DECLARATION

I, Katsuhiko Sato, of SHIGA INTERNATIONAL PATENT OFFICE, 3-1, Yaesu 2-chome, Chuo-ku, Tokyo, Japan, understand both English and Japanese, am the translator of the English document attached, and do hereby declare and state that the attached English document contains an accurate translation of the official certified copy of Japanese Patent Application No. 2002-334991 and that all statements made herein are true to the best of my knowledge.

Declared in Tokyo, Japan

This 9th day of October, 2007

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PATENT OFFICE
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this office.

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[Title of the Invention] CLUTCH CONTROL APPARATUS FOR HYBRID VEHICLE

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[Title of the Invention] CLUTCH CONTROL APPARATUS FOR HYBRID VEHICLE

[Claims]

[Claim 1] A clutch control apparatus for a hybrid vehicle having an engine and a motor as power sources, and an output shaft to which at least one of the driving powers of the engine and the motor is transmitted for driving the vehicle in an engine cruise mode in which the vehicle is driven by the engine, or in a motor cruise mode in which the vehicle is driven by the motor, the clutch control apparatus comprising:

a clutch means which is provided between the engine and motor and the output shaft, and which selectively disconnects the driving powers of the engine and motor from the output shaft; and

a clutch control means for controlling the engagement degree of the clutch means when the driving mode of the vehicle is alternately switched between the engine cruise mode and the motor cruise mode,

wherein the clutch control means executes a clutch relaxation control operation when the driving mode of the vehicle is switched between the engine cruise mode and the motor cruise mode, and executes an engagement increasing control operation in which the engagement degree of the clutch means is forced to increase when the revolution rate of the engine falls below a predetermined value.

[Claim 2] A clutch control apparatus according to claim 1, wherein the clutch relaxation control operation by the clutch control means is a control operation in which the engagement degree of the clutch means is gradually increased and recovered from a reduced engagement degree immediately after switching of the driving mode, and the engagement increasing control operation, which is executed depending on the revolution rate of the engine, is executed within a predetermined period that begins at the beginning of the clutch relaxation control operation.

[Claim 3] A clutch control apparatus according to claim 2, wherein an increment of increase in the engagement increasing control operation, which is executed depending on the revolution rate of the engine, is set to be less than that in the engagement recovery control operation.

[Claim 4] A clutch control apparatus according to any one of claims 1 to 3, wherein the predetermined value of the revolution rate of the engine is set corresponding to a recovery revolution rate at which fuel supply to the engine is resumed from a fuel cut

operation of the engine.

[Claim 5] A clutch control apparatus for a hybrid vehicle having an engine and a motor as power sources, and an output shaft to which at least one of the driving powers of the engine and the motor is transmitted for driving the vehicle in an engine cruise mode in which the vehicle is driven by the engine, or in a motor cruise mode in which the vehicle is driven by the motor, the clutch control apparatus comprising:

a clutch means which is provided between the engine and motor and the output shaft, and which selectively disconnects the driving powers of the engine and motor from the output shaft; and

a clutch control means for controlling the engagement degree of the clutch means when the driving mode of the vehicle is alternately switched between the engine cruise mode and the motor cruise mode,

wherein the clutch control means executes a clutch relaxation control operation when the driving mode of the vehicle is switched between the engine cruise mode and the motor cruise mode, and, during the clutch relaxation control operation, controls the engagement degree of the clutch means depending on the revolution rate of the engine.

[Claim 6] A clutch control apparatus according to claim 5, wherein the control operation for the engagement degree of the clutch means, which is executed depending on the revolution rate of the engine, is executed within a predetermined period that begins at the beginning of the clutch relaxation control operation, and the engagement degree of the clutch means is gradually increased and recovered after the predetermined period has passed.

[Claim 7] A clutch control apparatus according to any one of claims 1 to 6, wherein the clutch means is a starting clutch provided for an automatic transmission.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a clutch control apparatus for a vehicle, generally known as a hybrid vehicle, which includes, as power sources, an engine and a motor, the vehicle obtaining driving power from at least one of the engine and the motor.

[0002]

[Prior Art]

In recent years, in order to conserve fuel in the running of engines, or to reduce

exhaust gas produced by combustion of fuel, hybrid vehicles have been developed, each of which includes an engine and a motor, the motor also being capable of generating electrical energy (hereinafter referred to as a motor-generator) that are connected to a power transmission mechanism connected to driving wheels, and in which the motor-generator produces supplemental driving power depending on demand during normal travel of the vehicle, and the motor-generator is connected to the driving wheels so as to convert a portion of the kinetic energy of the vehicle into electrical energy, which is stored in a battery device (refer to, for example, Patent Document 1).

[0003]

In such hybrid vehicles, a hybrid vehicle is also known, in which an engine and a motor-generator are directly connected to each other. Conventionally, in such a hybrid vehicle, the motor-generator is not used solely for driving the vehicle (hereinafter this driving mode is referred to as a "motor cruise mode") because, in a motor cruise mode, the engine is a portion of the load for the motor-generator, and the motor-generator must produce power to compensate for the pumping loss and friction of the engine; therefore, fuel efficiency may not be improved when compared with the case in which the engine is used solely for driving the vehicle (hereinafter this driving mode is referred to as an "engine cruise mode").

[0004]

In the next development stage, a technology for reducing pumping loss of an engine has been developed, in which the operations of intake and exhaust valves of an engine are temporarily suspended, or closing timings of intake and exhaust valves are changed (see, for example, Patent Document 2). In the case of hybrid vehicles, it has been discovered that fuel efficiency can be improved by temporarily suspending the operations of intake and exhaust valves of an engine during a motor cruise mode so as to reduce pumping loss of the engine, even though the motor-generator is used solely for driving the vehicle and for compensating for engine friction when compared with the case of an engine cruise mode.

Moreover, a hybrid vehicle has been developed, in which the operations of intake and exhaust valves of an engine are temporarily suspended so that drive by motor is made possible (see, for example, Patent Document 3).

[0005]

[Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. H11-350995

[Patent Document 2]

Published Japanese Patent No. 3292224

[Patent Document 3]

Published Japanese Patent No. 3209046

[0006]

[Problems to be Solved by the Invention]

However, in such a hybrid vehicle which may be driven by a motor, a problem is encountered in that an unexpected deceleration feeling (hereinafter referred to as a drag feeling) or jolt is experienced when the driving mode of the vehicle is alternately switched between the motor cruise mode and the engine cruise mode.

More specifically, when the driving mode of the vehicle is switched from the engine cruise mode to the motor cruise mode, a drag feeling is experienced due to cut of fuel supply to the engine along with a jolt (vehicle vibration) due to changes in the engine friction by stopping the operations of the intake and exhaust valves. On the other hand, when the driving mode of the vehicle is switched from the motor cruise mode to the engine cruise mode, another drag feeling is experienced due to changes in the engine friction by starting the operations of the intake and exhaust valves along with a combustion initiation jolt due to start (ignition) of the engine operation.

In view of the above circumstances, an object of the present invention is to provide a hybrid vehicle in which drivability is improved, and vehicle behavior is stable even when the drive mode of the vehicle is switched back and forth between an engine cruise mode and a motor cruise mode.

[0007]

[Means for Solving the Problem]

In order to achieve the above object, the invention according to claim 1 is a clutch control apparatus for a hybrid vehicle (e.g., a hybrid vehicle 1 in an embodiment to be described below) having an engine (e.g., an engine 2 in an embodiment to be described below) and a motor (e.g., a motor-generator 3 in an embodiment to be described below) as power sources, and an output shaft (e.g., axle shafts 13a and 13b in an embodiment to be described below) to which at least one of the driving powers of the engine and the motor is transmitted for driving the vehicle in an engine cruise mode in which the vehicle is driven by the engine, or in a motor cruise mode in which the vehicle

is driven by the motor, the clutch control apparatus including: a clutch means (e.g., a starting clutch 12 in an embodiment to be described below) which is provided between the engine and motor and the output shaft, and which selectively disconnects the driving powers of the engine and motor from the output shaft; and a clutch control means (e.g., steps S501-S538 in an embodiment to be described below) for controlling the engagement degree of the clutch means when the driving mode of the vehicle is alternately switched between the engine cruise mode and the motor cruise mode, wherein the clutch control means executes a clutch relaxation control operation when the driving mode of the vehicle is switched between the engine cruise mode and the motor cruise mode, and executes an engagement increasing control operation in which the engagement degree of the clutch means is forced to increase when the revolution rate of the engine falls below a predetermined value.

[0008]

According to the clutch control apparatus configured as described above, the motor cruise mode can be effectively used in a driving state in which the engine cannot run with high efficiency. In addition, by executing the clutch relaxation control operation during a switching operation between the motor cruise mode and the engine cruise mode, a drag feeling due to a fuel cut operation can be reduced when the driving mode of the vehicle is switched from the engine cruise mode to the motor cruise mode, and a combustion initiation jolt due to start of the engine operation can also be reduced when the driving mode of the vehicle is switched from the motor cruise mode to the engine cruise mode.

Furthermore, by executing the engagement increasing control operation for the clutch means when the revolution rate of the engine falls below a predetermined value during the clutch relaxation control operation, the engine revolution rate will not decrease further, and the engine revolution rate can be increased; therefore, increase in vehicle jolt, which may occur due to decreased engine revolution rate, can be prevented, and the engine revolution rate can be prevented from reaching the recovery revolution rate at which fuel supply to the engine is resumed from a fuel cut operation of the engine.

[0009]

The invention according to claim 2 is a clutch control apparatus according to claim 1, wherein the clutch relaxation control operation by the clutch control means is a control operation in which the engagement degree of the clutch means is gradually

increased and recovered from a reduced engagement degree immediately after switching of the driving mode, and the engagement increasing control operation, which is executed depending on the revolution rate of the engine, is executed within a predetermined period (e.g., TMEVST and TMEVEND in an embodiment to be described below) that begins at the beginning of the clutch relaxation control operation.

According to the clutch control apparatus configured as described above, the engagement degree of the clutch means, which is once decreased by the engagement decreasing control operation, can be reliably recovered at the end of the switching operation between the driving modes.

[0010]

The invention according to claim 3 is a clutch control apparatus according to claim 2, wherein an increment (e.g., DKCLEV2 and DKCLENG2 in an embodiment to be described below) of increase in the engagement increasing control operation, which is executed depending on the revolution rate of the engine, is set to be less than that (e.g., DKCLEV1 and DKCLENG1 in an embodiment to be described below) in the engagement recovery control operation.

According to the clutch control apparatus configured as described above, the engine revolution rate can be increased without degrading effects of the clutch relaxation control operation even when the engagement increasing control operation is executed.

[0011]

The invention according to claim 4 is a clutch control apparatus according to any one of claims 1 to 3, wherein the predetermined value of the revolution rate of the engine is set corresponding to a recovery revolution rate at which fuel supply to the engine is resumed from a fuel cut operation of the engine.

According to the clutch control apparatus configured as described above, the engine revolution rate can be reliably maintained above the recovery revolution rate at which the fuel cut operation is switched to the fuel supply operation.

[0012]

The invention according to claim 5 is a clutch control apparatus for a hybrid vehicle (e.g., a hybrid vehicle 1 in an embodiment to be described below) having an engine (e.g., an engine 2 in an embodiment to be described below) and a motor (e.g., a motor-generator 3 in an embodiment to be described below) as power sources, and an output shaft (e.g., axle shafts 13a and 13b in an embodiment to be described below) to

which at least one of the driving powers of the engine and the motor is transmitted for driving the vehicle in an engine cruise mode in which the vehicle is driven by the engine, or in a motor cruise mode in which the vehicle is driven by the motor, the clutch control apparatus including: a clutch means (e.g., a starting clutch 12 in an embodiment to be described below) which is provided between the engine and motor and the output shaft, and which selectively disconnects the driving powers of the engine and motor from the output shaft; and a clutch control means (e.g., steps S601-S628 in an embodiment to be described below) for controlling the engagement degree of the clutch means when the driving mode of the vehicle is alternately switched between the engine cruise mode and the motor cruise mode, wherein the clutch control means executes a clutch relaxation control operation when the driving mode of the vehicle is switched between the engine cruise mode and the motor cruise mode, and, during the clutch relaxation control operation, controls the engagement degree of the clutch means depending on the revolution rate of the engine.

[0013]

According to the clutch control apparatus configured as described above, the motor cruise mode can be effectively used in a driving state in which the engine cannot run with high efficiency. In addition, by executing the clutch relaxation control operation, a drag feeling due to a fuel cut operation can be reduced when the driving mode of the vehicle is switched from the engine cruise mode to the motor cruise mode, and a combustion initiation jolt due to start of the engine operation can also be reduced when the driving mode of the vehicle is switched from the motor cruise mode to the engine cruise mode.

Furthermore, by controlling the engagement degree of the clutch means depending on the revolution rate of the engine during the clutch relaxation control operation, the engine revolution rate will not decrease to a level below a predetermined value; therefore, increase in vehicle jolt, which may occur due to decreased engine revolution rate, can be prevented, and the engine revolution rate can be prevented from reaching the recovery revolution rate at which fuel supply to the engine is resumed from a fuel cut operation of the engine.

[0014]

The invention according to claim 6 is a clutch control apparatus according to claim 5, wherein the control operation for the engagement degree of the clutch means,

which is executed depending on the revolution rate of the engine, is executed within a predetermined period (e.g., TMEVST and TMEVEND in an embodiment to be described below) that begins at the beginning of the clutch relaxation control operation, and the engagement degree of the clutch means is gradually increased and recovered after the predetermined period has passed.

According to the clutch control apparatus configured as described above, the engagement degree of the clutch means, which is once decreased by the engagement decreasing control operation, can be reliably recovered at the end of the switching operation between the driving modes.

[0015]

The invention according to claim 7 is a clutch control apparatus according to any one of claims 1 to 6, wherein the clutch means is a starting clutch provided for an automatic transmission.

According to the clutch control apparatus configured as described above, an additional clutch means is not necessary; therefore, the control apparatus can be simplified, and an increase in cost can be avoided.

[0016]

[Embodiments of the Invention]

Embodiments of the control apparatus for a clutch of a hybrid vehicle according to the present invention will be explained below with reference to FIGS. 1 to 25.

<First Embodiment>

A first embodiment of the control apparatus for a clutch of a hybrid vehicle according to the present invention will be explained below with reference to FIGS. 1 to 20.

FIG. 1 is a diagram showing the general structure of the driving power transmission system for a hybrid vehicle having the control apparatus for a clutch according to the present invention. The driving power transmission system of the hybrid vehicle 1 includes an engine 2, motor 3 (hereinafter referred to as a motor-generator) which is capable of generating electrical power, and which is disposed on an output shaft 2a of the engine 2, and a pulley and belt type continuously variable transmission (CVT) 5 connected to the engine output shaft 2a via a coupling mechanism 4.

[0017]

The engine 2 is a four-cylinder reciprocating engine in which pistons are respectively provided in four cylinders 7 formed in an engine block 6. The engine 2 includes an intake-exhaust control device 8 which controllably operates intake valves and exhaust valves for executing drawing and discharging operations of the cylinders 7, and a fuel injection and ignition control device 9 which controls fuel injection and ignition of injected fuel for each of the cylinders 7.

[0018]

As explained above, the motor-generator 3 is directly connected to the engine 2 so that at least one of the driving powers of the engine 2 and the motor-generator 3 is transmitted to driving wheels 14a and 14b via the continuously variable transmission 5. The motor-generator 3 is operated by a battery (not shown) installed on the vehicle so as to enable the vehicle to travel in a motor cruise mode, while on the other hand, the motor-generator 3 can generate power by being driven by the driving wheels 14a and 14b so as to charge the battery (a regenerative operation) during a deceleration traveling of the vehicle. In other words, the above driving power transmission system includes power sources arranged in a hybrid manner.

[0019]

The continuously variable transmission 5 comprises a metallic V-belt mechanism 30 provided on an input shaft 10 and a counter shaft 11, a forward-reverse switching mechanism 20 provided on the input shaft 10, and a starting clutch (a clutch section) 12 provided on the counter shaft 11. The input shaft 10 is connected to the engine output shaft 2a via the coupling mechanism 4. The driving power from the starting clutch 12 is transmitted to the right and left driving wheels 14a and 14b via a differential mechanism 13 and right and left axle shafts (output shafts) 13a and 13b.

[0020]

The metallic V-belt mechanism 30 includes a drive side movable pulley 31 provided on the input shaft 10, a driven side movable pulley 32 provided on the counter shaft 11, and a metallic V-belt 33 wound around the pulleys 31 and 32. The drive side movable pulley 31 includes a fixed pulley half 34 provided on the input shaft 10 in a rotatable manner, and a movable pulley half 35 which is made movable in an axial direction with respect to the fixed pulley half 34. There is provided a drive side cylinder chamber 37, which is delimited by a cylinder wall 36, in the right of the movable pulley half 35 in FIG. 1. A drive side lateral pressure for making the movable

pulley half 35 move in the axial direction is produced by providing a pulley controlling oil pressure in the drive side cylinder chamber 37 from a control valve 15 via an oil passage 38.

[0021]

The driven side movable pulley 32 includes a fixed pulley half 39 provided on the counter shaft 11, and a movable pulley half 40 which is made movable in an axial direction with respect to the fixed pulley half 39. There is provided a driven side cylinder chamber 42, which is delimited by a cylinder wall 41, in the left of the movable pulley half 40 in FIG. 1. A driven side lateral pressure for making the movable pulley half 40 move in the axial direction is produced by providing a pulley controlling oil pressure in the driven side cylinder chamber 42 from a control valve 15 via an oil passage 43.

[0022]

The oil pressures (the drive side lateral pressure and driven side lateral pressure) provided to the cylinders 37 and 42 are controlled by the control valve 15 so that lateral pressures sufficient to prevent slip of the metallic V-belt 33 are provided. A further control is selectively executed so that the drive side lateral pressure and driven side lateral pressure differ from each other, whereby groove widths of the pulleys 31 and 32 are changed so as to change wound radiuses of the metallic V-belt 33 in order to change transmission speed ratio in a stepless manner.

[0023]

The forward-reverse switching mechanism 20, which is formed by a planetary gear mechanism, includes a sun gear connected to the input shaft 10, a ring gear 22 connected to the fixed pulley half 34 of the drive side movable pulley 31, a carrier 23 which is selectively fixed by a reversing brake 27, and a forward clutch 25 which selectively connects the sun gear 21 to the ring gear 22. In the forward-reverse switching mechanism 20, when the forward clutch 25 is engaged, all gears 21, 22, and 22 rotate with the input shaft 10, and the drive side movable pulley 31 is rotated by the engine 2 or the motor-generator 3 in a direction which is the same as that of the input shaft 10 (i.e., in the forward direction). On the other hand, when the reversing brake 27 is engaged, because the carrier 23 is fixed, the ring gear 22 is driven in a direction opposite to that of the sun gear 21, and the drive side movable pulley 31 is rotated in a direction opposite to that of the input shaft 10 (i.e., in the reverse direction). The

engagement operations of the forward clutch 25 and reversing brake 27 are controlled by a forward-reverse control oil pressure which is set in the control valve 15 using a line pressure.

[0024]

The starting clutch 12 is a clutch controlling power transmission from the counter shaft 11 to output elements, i.e., to power transmission gears 16a, 16b, 17a, and 17b. Driving power is transmitted to the output elements when the starting clutch 12 is engaged. Accordingly, when the starting clutch 12 is engaged, the output power of the engine 2 or motor 3, while driving speed is changed through the metallic V-belt mechanism 30, is transmitted to the differential mechanism 13 via the power transmission gears 16a, 16b, 17a, and 17b, and then the driving power is split by the differential mechanism 13, and the split driving powers are transmitted to the driving wheels 14a and 14b via the right and left axle shafts 13a and 13b. When the starting clutch 12 is disengaged, power transmission is not performed, and the transmission 5 is placed in a neutral state. The engagement control of the starting clutch 12 is executed by a clutch control oil pressure which is set in the control valve 15 using a line pressure, and which is supplied via an oil passage 18.

[0025]

In the continuously variable transmission 5 configured as explained above, a speed change control is executed by the drive and driven sides lateral pressures produced by using oil pressure provided by the control valve 15 via the oil passages 38 and 43, a forward-reverse switching control is executed by the forward-reverse control oil pressure supplied to the forward clutch 25 and the reversing brake 27 via oil passages (not shown), and a starting clutch engagement control is executed by the clutch control oil pressure supplied via the oil passage 18. The operation of the control valve 15 is controlled by control signals provided from an electrical control unit (hereinafter abbreviated as an ECU) 19.

[0026]

In the engine 2, an all-cylinder deactivation operation can be executed, in which all four cylinders are deactivated in a predetermined operation state (e.g., a deceleration operation, or motor cruise operation which will be explained below). In other words, the ECU 19 controls the operation of the intake-exhaust control device 8 via a control line 53, and controls the operation of the fuel injection and ignition control device 9 via a

control line 54 so as to close the intake and exhaust valves of all cylinders 7, and so as to stop fuel injection and ignition, and thus an all cylinder deactivation operation can be executed. By executing the all cylinder deactivation operation, fuel efficiency during a deceleration operation can be improved, the friction of the engine 2 can be reduced, and the kinetic energy of the vehicle during a deceleration operation can be effectively recovered by the regenerative operation of the motor-generator 3.

The mechanism (cylinder deactivation mechanism) with which the intake and exhaust valves are maintained in a closed state is not limited to a specific one, and a mechanism in which the operations of the valves are stopped by using a hydraulic control, or a mechanism in which the intake and exhaust valves consist of electromagnetic valves whose operations are selectively stopped, may be employed.

[0027]

To the ECU 19, a revolution sensor 61 which measures the revolution rate of the engine output shaft 2a, an intake pressure sensor 62 which measures the intake negative pressure of the engine 2, a throttle opening degree sensor 63 which measures the throttle opening degree of the engine 2, a vehicle speed sensor 64 which measures the traveling speed of the hybrid vehicle 1, are electrically connected so that output signals corresponding to measured values measured by the sensors 61 to 62 are input into the ECU 19.

[0028]

In the hybrid vehicle 1 including the power transmission system configured as described above, in order to improve fuel efficiency during a cruise operation, two cruise modes are provided, i.e., (1) a motor cruise mode (in which the vehicle is driven by the motor-generator), and (2) an engine cruise mode (in which the vehicle is driven by the engine). It should be noted that, in the following description, “motor cruise” may be referred to as “EV cruise”, and “engine cruise” may be referred to as “ENG cruise”.

More specifically, the motor cruise mode, in which the vehicle is driven solely by the motor-generator 3, is selected when the vehicle travels under low load conditions, which may degrade fuel efficiency, and the engine cruise mode, in which the vehicle is driven solely by the engine 2, is selected when the engine 2 can be operated while obtaining preferable fuel efficiency.

[0029]

In the motor cruise mode, a control operation is executed in which fuel supply to

all of the cylinders of the engine 2 is stopped, and all of the cylinders are deactivated, i.e., the intake and exhaust valves of all of the cylinders are maintained in a closed state so that pumping loss is reduced, and in addition, a motor output control is executed in which the motor-generator 3 generates electrical power which corresponds to pumping loss and friction of the engine 2 and to kinetic energy of the vehicle. On the other hand, in the engine cruise mode, the motor-generator 3 does not output driving power. The operation of the motor-generator 3 is controlled by the control signals provided by the ECU 19 via a control line 51.

In addition, in the engine cruise mode, a gear ratio selecting control is also executed so that an optimum gear ratio is selected in order to operate the engine 2 under conditions for obtaining better fuel efficiency. Such a control is performed by the control signals sent from the ECU 19 to the control valve 15 via a control line 52.

[0030]

As mentioned above, if the driving mode of the vehicle is switched from the engine cruise mode to the motor cruise mode immediately, or from the motor cruise mode to the engine cruise mode immediately, a drag feeling or jolt is experienced due to stop or restart of the engine operation, or stop or restart of the operations of the intake and exhaust valves; therefore, in the hybrid vehicle 1 of the present embodiment, the output power of the motor-generator 3 and the engagement degree of the starting clutch 12 are controlled so as to improve drivability and to stabilize vehicle behavior when the driving mode is switched.

[0031]

<Switching operation from the EV cruise mode to the ENG cruise mode>

A switching operation from the engine cruise mode to the motor cruise mode will be explained below with reference to the timing chart shown in FIG. 2.

In FIG. 2, the vehicle travels in the engine cruise mode before time t0, and a mode switching operation from the engine cruise mode to the motor cruise mode begins (an EV request) at time t0.

In the engine cruise mode, the engine 2 runs in an all-cylinder activation mode, and the motor-generator 3 outputs no power. The starting clutch 12 is in an engaged state in which a starting clutch oil pressure correction coefficient is set to be 1.0 (i.e., correction is not enforced), which means that the oil pressure for the starting clutch 12 is set to be a desired oil pressure for the starting clutch during engine cruise mode

(hereinafter, this is referred to as a clutch oil pressure CMD in normal mode).

[0032]

Upon receiving the EV request, the desired oil pressure for the starting clutch is decreased so as to execute an engagement decreasing control operation in which the engagement degree of the starting clutch 12 is decreased. In this case, the desired oil pressure for the starting clutch is obtained by multiplying the clutch oil pressure CMD in normal mode by the starting clutch oil pressure correction coefficient.

[0033]

Upon receiving the EV request, the fuel cut operation (hereinafter, this may be abbreviated as F/C) of the engine 2 begins at time t1, and fuel supply to the cylinders and ignitions therein are stopped from one cylinder to the next. As a result, the output power of the engine (ENG output) is decreased stepwise. At this stage, open and close operations of the intake and exhaust valves of all of the cylinders are still executed, whereby unburned fuel is completely expelled. In synchrony with decrease in output power of the engine 2, i.e., in synchrony with combustion timing of the engine 2, the motor-generator 3 is controlled so as to output driving power, whereby the source of the driving power is switched from the engine 2 to the motor-generator 3 stepwise. In this case, the motor-generator 3 is controlled so as to output an amount of driving power corresponding not only to the driving power produced by the cylinders to which fuel supply has stopped, but also to the friction (including pumping loss) of the same cylinders. In other words, the motor-generator 3 is controlled so as to output power including power for compensating for the engine friction, which is manifested by fuel cutting, in addition to the driving power necessary for driving the vehicle by the motor-generator 3. The fuel cut operations for all of the cylinders are completed at time t2.

By controlling the motor-generator 3 in such a manner, the driving source is smoothly switched from the engine 2 to the motor-generator 3 without there being variation in the driving power. In addition, because the engagement decreasing control operation for the starting clutch 12 is executed, a drag feeling due to the fuel cut operation can be reduced, vehicle behavior is stabilized, and drivability can be improved.

[0034]

Then, at time t3, an all-cylinder deactivation command is provided to the engine 2. Upon receiving the all-cylinder deactivation command, the cylinder deactivation

operation begins at time t4, and the intake and exhaust valves are made to be closed from one cylinder to the next. As a result, because pumping loss of the engine 2 is decreased stepwise, the motor-generator 3 is controlled so that the output power thereof is decreased stepwise by an amount corresponding to the reduced pumping loss per cylinder. At time t6, the intake and exhaust valves of all of the cylinders are completely closed, which means that an all-cylinder deactivation operation is completed.

By controlling the output power of the motor-generator 3 in such a manner, changes in the engine friction due to stop of the operations of the intake and exhaust valves can be compensated by the change in the output power of the motor-generator 3; therefore, a vehicle jolt can be prevented, and drivability may be improved.

[0035]

During the transition of the source of the driving power from the engine 2 to the motor-generator 3, the desired oil pressure for the starting clutch, which has been decreased, is gradually increased so that the degree of the starting clutch 12 is increased. In this case, the desired oil pressure for the starting clutch is obtained by multiplying the clutch oil pressure CMD in normal mode by the starting clutch oil pressure correction coefficient, and the starting clutch oil pressure correction coefficient is gradually increased.

Then, at time t7, correction of the desired oil pressure for the starting clutch is finished, i.e., the starting clutch oil pressure correction coefficient is made to be 1.0, and the desired oil pressure for the starting clutch 12 is set to be a desired oil pressure for the starting clutch in motor cruise mode (hereinafter, this is referred to as a clutch oil pressure CMD in EV mode).

As described above, because the desired oil pressure for the starting clutch is gradually increased so that the engagement degree of starting clutch 12 is gradually recovered by the time the cylinder deactivation of all cylinders is completed, a vehicle jolt due to engagement of the starting clutch 12 can be avoided.

Moreover, because the engagement degree, which is once decreased at the transition from the engine cruise mode to the motor cruise mode, is reliably recovered at completion of the transition of the driving mode, energy loss due to the clutch relaxation control operation can be minimized.

[0036]

When the clutch relaxation control operation for the starting clutch 12 is

executed upon receiving the EV request, the engine revolution rate is decreased. If the starting clutch oil pressure correction coefficient is maintained for a long time, during the clutch relaxation control operation, at a level which was set immediately after receiving the EV request, as shown by a broken line in FIG. 2, the engine revolution rate NE decreases to a level lower than a predetermined revolution rate, as shown by another broken line in FIG. 2, which may increase vibration of the vehicle. In addition, the fuel cut operation should be continued after being initiated at time t1; however, when the engine revolution rate decreases to a F/C recovery revolution rate, at which the fuel cut operation is stopped and a fuel supply operation is resumed, a request for recovery from F/C is received based on the engine revolution rate, and the Recovery revolution rate is executed (i.e., the fuel supply operation is resumed). As a result, the engine 2 may be unnecessarily supplied with fuel, and thereby fuel efficiency may be decreased.

[0037]

In order to solve the above problem, in this embodiment, when the engine revolution rate decreases to a predetermined value (NELOW) during the clutch relaxation control operation for the starting clutch 12, as shown by a solid line in FIG. 2, an engagement increasing control operation, in which the starting clutch oil pressure correction coefficient is increased so as to force the increase in the engagement degree of the starting clutch 12, is executed, so that the engine revolution rate is increased, and there is no further decrease. As a result, increase in vehicle jolt, which may occur because the engine revolution rate is decreased, can be prevented, and drivability can be further improved.

Moreover, in this embodiment, by determining the predetermined value (NELOW) depending on the F/C recovery revolution rate, the engine revolution rate will not reach the F/C recovery revolution rate. As a result, unnecessary fuel supply to the engine 2 due to the recovery operation from F/C can be reliably prevented, and fuel efficiency can be improved.

[0038]

<Switching operation from the EV cruise mode to the ENG cruise mode>

Next, a switching operation from the motor cruise mode to the engine cruise mode will be explained below with reference to the timing chart shown in FIG. 3.

In FIG. 3, the vehicle travels in the motor cruise mode before time t0, and a mode switching operation from the motor cruise mode to the engine cruise mode begins

(a request for recovery from the cylinder deactivation operation is made) at time t0.

[0039]

Upon receiving the request for recovery from the cylinder deactivation operation, the desired oil pressure for the starting clutch is decreased so as to execute the engagement decreasing control operation in which the engagement degree of the starting clutch 12 is decreased. In this case, the desired oil pressure for the starting clutch is obtained by multiplying the clutch oil pressure CMD in normal mode by the starting clutch oil pressure correction coefficient.

[0040]

Based on the request for recovery from the cylinder deactivation operation, recovery from the cylinder deactivation operation of the engine 2 begins at time t1, and the operations of the intake and exhaust valves are resumed from one cylinder to the next. At this stage, fuel supply to all of the cylinders and ignitions therein are maintained to be stopped. As a result, because pumping loss of the engine 2 is increased stepwise, the motor-generator 3 is controlled so that the output power thereof is increased stepwise by an amount corresponding to the increasing pumping loss per cylinder. At time t2, the operations of the intake and exhaust valves of all of the cylinders are completely resumed.

By controlling the output power of the motor-generator 3 in such a manner, increase in the pumping loss due to resuming of the operations of the intake and exhaust valves can be compensated by the change in the output power of the motor-generator 3; therefore, a drag feeling can be reduced, and drivability may be improved.

[0041]

Then, at time t3, a command for starting the recovery operation from F/C is provided to the engine 2. Upon receiving the command for starting the recovery operation from F/C, the fuel supply and ignition are resumed at time t4, and are executed from one cylinder to the next. As a result, the output power of the engine (ENG output) is increased stepwise. In synchrony with the increase in the output power of the engine 2, i.e., in synchrony with the combustion timing of the engine 2, the motor-generator 3 is controlled so as to output driving power, whereby the source of the driving power is switched from the motor-generator 3 to the engine 2 stepwise. In this case, the motor-generator 3 is controlled so that the output power of the motor-generator 3 is decreased by an amount of driving power corresponding not only to the driving power

produced by the cylinders to which fuel supply has resumed, but also to the friction (including pumping loss) of the same cylinders. At time t6, the fuel supply to all of the cylinders is completely resumed, and the switching operation from the motor cruise mode to the engine cruise mode is completed.

[0042]

By controlling the motor-generator 3 in such a manner, the driving source is smoothly switched from the motor-generator 3 to the engine 2 without there being variation in the driving power. At the same time, because the correction of the desired oil pressure for the starting clutch is executed so as to decrease the engagement degree of starting clutch 12, a combustion initiation jolt due to start of the engine operation can be reduced, vehicle behavior is stabilized, and drivability can be improved.

[0043]

During the transition of the source of the driving power from the engine 2 to the motor-generator 3, the desired oil pressure for the starting clutch, which was once decreased, is gradually increased so as to gradually increase the engagement degree of starting clutch 12. In this case, the desired oil pressure for the starting clutch is obtained by multiplying the clutch oil pressure CMD in normal mode by the starting clutch oil pressure correction coefficient, and the starting clutch oil pressure correction coefficient is gradually increased.

By the completion of the transition of the driving mode, the correction of the desired oil pressure for the starting clutch is finished, i.e., the starting clutch oil pressure correction coefficient is set to be 1.0, and the desired oil pressure for the starting clutch is set to be the clutch oil pressure CMD in normal mode.

In this manner, because the desired oil pressure for the starting clutch is gradually increased so as to gradually increase and recover the engagement degree of starting clutch 12 by the time the fuel supply to all of the cylinders is completely resumed, a vehicle jolt due to engagement of the starting clutch 12 can be avoided.

Moreover, because the engagement degree of the starting clutch 12, which is once decreased at the transition from the engine cruise mode to the motor cruise mode, is reliably recovered at completion of the transition of the driving mode, energy loss due to the clutch relaxation control operation can be minimized.

[0044]

When the clutch relaxation control operation for the starting clutch 12 is

executed upon receiving a request for the ENG cruise mode (i.e., a request for recovery from the cylinder deactivation operation), the engine revolution rate is decreased. If the starting clutch oil pressure correction coefficient is maintained for a long time, during the clutch relaxation control operation, at a level which was set immediately after receiving the request for recovery from the cylinder deactivation operation, as shown by a broken line in FIG. 3, the engine revolution rate NE decreases to a level lower than a predetermined revolution rate, as shown by another broken line in FIG. 3, which may increase vibration of the vehicle. In addition, the fuel cut operation should be continued until time t3 at which the recovery operation from F/C is started; however, when the engine revolution rate decreases to the F/C recovery revolution rate, at which the fuel cut operation is stopped and a fuel supply operation is resumed, a request for the recovery operation from F/C is received based on the engine revolution rate, and the fuel cut operation is cancelled (i.e., the fuel supply operation is resumed). As a result, the engine 2 may be unnecessarily supplied with fuel, and thereby fuel efficiency may be decreased.

[0045]

In order to solve the above problem, in this embodiment, when the engine revolution rate decreases to a predetermined value (NELOW) during the clutch relaxation control operation for the starting clutch 12, as shown by a solid line in FIG. 3, an engagement increasing control operation, in which the starting clutch oil pressure correction coefficient is increased so as to force the increase in the engagement degree of the starting clutch 12, and is executed, so that the engine revolution rate is increased, and there is no further decrease. As a result, increase in vehicle jolt, which may occur because the engine revolution rate is decreased, can be prevented, and drivability can be further improved.

Moreover, in this embodiment, by determining the predetermined value (NELOW) depending on the F/C recovery revolution rate, the engine revolution rate will not reach the F/C recovery revolution rate. As a result, unnecessary fuel supply to the engine 2 due to the recovery operation from F/C can be reliably prevented, and fuel efficiency can be improved.

In FIGS. 2 and 3, the ESC (%) indicates the revolution ratio between the input side and the output side of the starting clutch 12, and when the ESC is 100%, there is no slip therebetween, i.e., the starting clutch 12 is in a completely engaged state. "NE" is

the engine revolution rate.

[0046]

<During deceleration of the vehicle after the EV cruise mode>

When the output power of the motor-generator 3 is made to be zero while maintaining the clutch oil pressure at a level as in the motor cruise mode, or when a regenerative braking operation is executed during deceleration of the vehicle after the motor cruise mode, an unexpected drag feeling or jolt of the vehicle may be experienced. Therefore, in the hybrid vehicle 1 of this embodiment, a drag feeling or jolt of the vehicle is prevented by executing the clutch relaxation control operation for the starting clutch 12 during deceleration of the vehicle after the motor cruise mode as well. Deceleration of the vehicle after the motor cruise mode is, in other words, a transition from the motor cruise mode to a state in which the engine is operated (i.e., a deceleration operation with the fuel cut operation).

[0047]

Operation during deceleration of the vehicle after the motor cruise mode will be explained below with reference to the timing chart shown in FIG. 4.

In FIG. 4, the vehicle travels in the motor cruise mode before time t0, and a request for deceleration is made at time t0.

Upon receiving the request for deceleration, the output power of the motor-generator 3 is made to be zero, and at the same time, the desired oil pressure for the starting clutch is decreased so as to execute the engagement decreasing control operation in which the engagement degree of the starting clutch 12 is decreased. In this case, the desired oil pressure for the starting clutch is obtained by multiplying the clutch oil pressure CMD in normal mode by the starting clutch oil pressure correction coefficient. When the engagement degree of the starting clutch 12 is decreased, a drag feeling due to engine brake or regenerative braking is reduced, and drivability can be improved.

[0048]

After executing the above control operation, in order to obtain a large magnitude of engine braking or regenerative braking, the desired oil pressure for the starting clutch, which was once decreased, is gradually increased, so as to gradually increase the engagement degree of starting clutch 12. In this case, the desired oil pressure for the starting clutch is obtained by multiplying the clutch oil pressure CMD in normal mode by

the starting clutch oil pressure correction coefficient, and the starting clutch oil pressure correction coefficient is gradually increased.

In this manner, because the desired oil pressure for the starting clutch is gradually increased so as to gradually increase and recover the engagement degree of starting clutch 12, a vehicle jolt due to engagement of the starting clutch 12 can be avoided, and drivability can be improved.

When an idling stop command is sent at time t2, the starting clutch 12 is disengaged, and fuel supply is stopped so that the engine revolution rate becomes zero. Moreover, at time t3, the vehicle speed becomes zero. i.e., the hybrid vehicle 1 stops.

[0049]

When the clutch relaxation control operation for the starting clutch 12 is executed during deceleration of the vehicle after the motor cruise mode, the engine revolution rate is decreased. If the starting clutch oil pressure correction coefficient is maintained for a long time up to time t1, during the clutch relaxation control operation, at a level which was set immediately after receiving the request for deceleration, as shown by a broken line in FIG. 4, the engine revolution rate NE decreases to a level lower than a predetermined revolution rate, as shown by another broken line in FIG. 4, which may increase vibration of the vehicle. In addition, the fuel cut operation should be continued as long as deceleration continues; however, when the engine revolution rate decreases to the F/C recovery revolution rate, at which the fuel cut operation is stopped and a fuel supply operation is resumed, a request for the recovery operation from F/C is received based on the engine revolution rate, and the recovery operation from F/C is executed (i.e., the fuel supply operation is resumed). As a result, the engine 2 may be unnecessarily supplied with fuel, and thereby fuel efficiency may be decreased.

[0050]

In order to solve the above problem, in this embodiment, when the engine revolution rate decreases to a predetermined value (NELOW) during the clutch relaxation control operation for the starting clutch 12, as shown by a solid line in FIG. 4, an engagement increasing control operation, in which the starting clutch oil pressure correction coefficient is increased so as to force the increase in the engagement degree of the starting clutch 12, is executed, so that the engine revolution rate is increased, and there is no further decrease. As a result, increase in vehicle jolt, which may occur because the engine revolution rate is decreased, can be prevented, and drivability can be

further improved.

Moreover, in this embodiment, by determining the predetermined value (NELOW) depending on the F/C recovery revolution rate, the engine revolution rate will not reach the F/C recovery revolution rate. As a result, unnecessary fuel supply to the engine 2 due to the recovery operation from F/C can be reliably prevented, and fuel efficiency can be improved.

[0051]

Next, the driving mode switching operation (including during deceleration of the vehicle after the motor cruise mode) will be more specifically explained with reference to the flowcharts shown in FIGS. 5 to 20.

<EV mode main routine>

The main control routine of the EV mode will be explained with reference to the flowchart shown in FIG. 5.

The flowchart shown in FIG. 5 shows the main control routine of the EV mode, which is repeatedly and periodically executed by the ECU 19.

First, in step S101, an engine friction ENGFRIC1, which is the friction of the engine 2 in an all-cylinder operation state, is retrieved from an ENGFRIC1 map or table shown in FIG. 6 depending on the engine revolution rate NE and an intake negative pressure Pb.

Then, the control operation proceeds to step S102, in which an engine friction ENGFRIC2, which is the friction of the engine 2 in an all-cylinder deactivation state, is retrieved from an ENGFRIC2 map or table, represented by FIG. 7, depending on the engine revolution rate NE.

[0052]

Next, the operation proceeds to step S103, in which a control operation for determining permission of cylinder deactivation is executed in order to determine whether or not the engine 2 may be placed in the all-cylinder deactivation state.

Then, the operation proceeds to step S104, in which the control operation for determination of cruise EV request mode is executed for determining whether or nor the EV cruise mode is permitted. In this embodiment, executing the control operation for determination of cruise EV request in step S104 corresponds to a driving mode determining section. The control operation for determination of cruise EV request will be explained below in detail.

[0053]

Next, the operation proceeds to step S105, in which a control operation for determining current status regarding the EV cruise mode is executed for determining current status regarding the EV cruise mode. More specifically, in this operation, it is determined whether or not the vehicle is in the EV cruise mode, whether the vehicle is entering into the EV cruise mode, or whether the driving mode is being switched to the engine cruise mode.

When it is determined, in step S105, that the vehicle is entering into the EV cruise mode, the operation proceeds to step S106 in which a control pre-operation for starting the EV cruise mode is executed, when it is determined that the vehicle is in the EV cruise mode, the operation proceeds to step S107 in which a control operation for the EV cruise mode is executed, and when it is determined that the driving mode is being switched to the engine cruise mode, the operation proceeds to step S108 in which a control pre-operation for finishing the EV cruise mode is executed, and when it is determined that the vehicle is not in the EV cruise mode (i.e., the engine is being operated) the operation proceeds to step S110. The control pre-operation for starting the EV cruise mode and the control pre-operation for finishing the EV cruise mode will be explained below in detail.

[0054]

After executing the control pre-operation for starting the EV cruise mode in step S106, or after executing the EV operation in step S107, or after executing the control pre-operation for finishing the EV cruise mode in step S108, the operation proceeds to step S109, in which an initial value #TINHEV is set into a busy prevention timer TMINHEV.

Then, the operation proceeds to step S110, in which it is determined whether the counter value of the busy prevention timer TMINHEV is equal to or greater than "0". When the result of the determination is "YES", i.e., TMINHEV>0, the operation proceeds to step S111, in which "1" is subtracted from the counter value of the busy prevention timer TMINHEV, and then the control operation in this routine is terminated. In contrast, when the result of the determination is "NO", i.e., TMINHEV≤0, the control operation in this routine is terminated without executing the control operation in step S111.

[0055]

More specifically, when the operation proceeds to the control pre-operation for starting the EV cruise mode, to the control operation for the motor cruise mode, or to the control pre-operation for finishing the EV cruise mode by the determination in step S105, the counter value of busy prevention timer TMINHEV is maintained to be the initial value #TINHEV; however, in contrast, when it is determined, in the control operation for determining current status regarding the EV cruise mode in step S105, that the vehicle is not in the motor cruise mode, "1" is subtracted from the counter value of the busy prevention timer TMINHEV every time this control routine is executed.

[0056]

<Control operation for determination of request for the cruise EV>

Next, the control operation for determination of request for the EV cruise mode in step S104 will be explained with reference to the flowcharts shown in FIGS. 8 and 9.

In step S201, a desired output power of the vehicle (hereinafter simply referred to as a desired output power) PWRRQ, which is the output power needed for driving the vehicle, is retrieved from the desired output power map or table shown in FIG. 10 depending on the engine revolution rate NE and an opening degree of throttle TH.

Next, the operation proceeds to step S202, in which the control operation for filtering the desired output power is executed. More specifically, a maximum range of changes in the desired output power has been set in advance, the difference between the current desired output power PWRRQ determined in step S201 in the present routine and the previous desired output power PWRRQ determined in step S201 in the immediately previous routine are calculated, and when the difference is greater than the maximum range for changes in the desired output power, the desired output power PWRRQ is limited to the limit values of the range.

By limiting the range of changes in the desired output power in such a manner, a frequent switching of the driving mode between the ENG cruise mode and the EV cruise mode, i.e., a hunting phenomenon, is prevented, so that drivability is improved, while on the other hand, increase in fuel consumption of the engine 2 associated with switching of the driving mode and increase in power of the motor-generator 3 are minimized.

In this embodiment, executing the control operation in step S202 corresponds to a filter limiting the range of changes in the desired output power.

[0057]

Next, the operation proceeds to step S203, in which it is determined whether the

vehicle is in a cruise mode. When the result of the determination is "YES", the operation proceeds to step S204, and when the result of the determination is "NO", which means that the motor cruise mode is not permitted, the operation proceeds to step S212.

In step S204, it is determined whether the state of charge of the battery is sufficient for the motor cruise mode. When the result of the determination is "YES", i.e., the state of charge of the battery is sufficient for the motor cruise mode, the operation proceeds to step S205, and when the result of the determination is "NO", i.e., the state of charge of the battery is not sufficient for the EV cruise mode, the operation proceeds to step S212.

[0058]

In step S205, it is determined whether the value of a cylinder deactivation permission flag F_KYUTOENB is "0". The cylinder deactivation permission flag F_KYUTOENB is set to be "0" when the cylinder deactivation operation is permitted, and is set to be "1" when the cylinder deactivation operation is not permitted. When the result of the determination in step S205 is "YES", i.e., F_KYUTOENB=0, the operation proceeds to step S206, and when the result of the determination is "NO", i.e., F_KYUTOENB=1, the operation proceeds to step S212.

[0059]

In step S206, it is determined whether the counter value of the busy prevention timer TMINHEV is equal to "0". When the result of the determination is "YES", the operation proceeds to step S207, and when the result of the determination is "NO", the operation proceeds to step S212. When the result of the determination in step S206 is not "YES", i.e., TMINHEV≠0, a cruise EV request flag F_EVREQ is not set to "1" in step S211, i.e., the EV cruise mode is not requested, which will be explained below. This control means that the EV cruise mode is not permitted unless the ENG cruise mode has been maintained for a predetermined time period when the driving mode is switched from the ENG cruise mode to the EV cruise mode, whereby a frequent switching of the driving mode between the ENG cruise mode and the EV cruise mode, i.e., a hunting phenomenon, is prevented, so that drivability is improved, while on the other hand, increase in fuel consumption of the engine 2 associated with switching of the driving mode and increase in power of the motor-generator 3 are minimized.

[0060]

In step S207, a PWRREQFIN is calculated. The PWRREQFIN is calculated

by adding the engine friction ENGFRIC1 determined in step S101 to the desired output power PWRRQ after filtering in step S202, i.e., PWRREQFIN=PWRRQ+ENGFRIC1.

Next, the operation proceeds to step S208, in which a cruise EV required output power EVPWR (motor cruise enabling output power) is retrieved from a map or table of cruise EV required output power, represented by FIG. 11, depending on the current vehicle speed. The cruise EV required output power EVPWR is the output power of the motor needed for the motor cruise mode which is set depending on the vehicle speed. In FIG. 11, the two-dot chain line indicates road load, i.e., the minimum motor power needed for cruise, the EVPWR is set to be greater than the road load, and there is provided a hysteresis for preventing a hunting phenomenon.

[0061]

Next, the operation proceeds to step S209, in which it is determined whether the PWRREQFIN calculated in step S207 is equal to or less than a maximum motor output power LIMPWR. The maximum motor output power LIMPWR is the power of the motor-generator 3 obtainable with the current state of charge of the battery 9. More specifically, in step S209, it is determined whether or not the motor output power, which is needed for driving when the engine 2 is placed in the all-cylinder deactivation state (i.e., the motor output power needed time t2 to time t4 in FIG. 2), is obtainable with the current state of charge of the battery 9. When the result of the determination in step S209 is “YES”, i.e., PWRREQFIN≤LIMPWR, the operation proceeds to step S210, and when the result of the determination is “NO”, i.e., PWRREQFIN>LIMPWR, which means that switching to the EV cruise is not possible, and then the operation proceeds to step S212.

[0062]

In step S210, it is determined whether the desired output power PWRRQ after filtering in step S202 is equal to or less than the cruise EV required output power EVPWR determined in step S208.

When the result of the determination in step S210 is “YES”, i.e., PWRRQ≤EVPWR, the operation proceeds to step S211, in which the cruise EV request flag F_EVREQ is set to be “1” because the EV cruise mode is requested, and then the control operation in this routine is terminated.

In contrast, when the result of the determination in step S210 is “NO”, i.e., PWRRQ>EVPWR, which means that the EV cruise is not possible, the operation

proceeds to step S212.

In step S212, it is deemed that the EV cruise is not requested, and the cruise EV request flag F_EVREQ is set to be "0", and then the control operation in this routine is terminated.

[0063]

<Control pre-operation for starting the EV cruise mode>

Next, the control pre-operation for starting the EV cruise mode in step S106 in the main control routine of the EV cruise mode will be explained with reference to the flowcharts shown in FIGS. 12 and 13.

In step S301, a fuel cut request flag F_FCREQ is set to be "1", and the operation proceeds to step S302, in which it is determined whether a fuel cut flag F_FC is "1" or "0". Note that when F_FC is "1", a fuel cut operation is being executed, and when F_FC is "0", a fuel cut operation is not being executed.

[0064]

When it is determined in step S302 that F_FC is "1", the operation proceeds to step S303, and when it is determined that F_FC is "0", the operation proceeds to step S304.

In step S303, it is determined whether the result of the determination, which is made in the control operation for determining current status regarding the EV cruise mode in step S105 in the main control routine of the EV cruise mode in the immediately previous routine, is "the control pre-operation for starting the EV cruise mode" (i.e., whether or not EVSTATUS_OLD=START). When the result of the determination in step S303 is "YES", i.e., the status regarding the EV cruise mode in the previous routine was "the control pre-operation for starting the EV cruise mode", the operation proceeds to step S305. In contrast, when the result of the determination in step S303 is "NO", i.e., the status regarding the EV cruise mode in the previous routine was not "the control pre-operation for starting the EV cruise mode", which means that this routine is the first-time execution of the control pre-operation for starting the EV cruise mode, the operation proceeds to step S304.

[0065]

In step S304, a TDC counter TDCEVST for the control pre-operation for starting the EV cruise mode is set to be an initial value "#STDLY1+#STDLY2+#STDLY3+#STDLY4+#STDLY5", i.e.,

TDCEVST=#STDLY1+#STDLY2+#STDLY3+#STDLY4+#STDLY5.

Then, the operation proceeds to step S305.

[0066]

FIG. 14 is a timing chart showing a calculated final motor output power CMDEVPWR in the control pre-operation for starting the EV cruise mode, and more specifically, FIG. 14 shows relationships among the CMDEVPWR, the STDLYs, and the status regarding the control pre-operation for starting the EV cruise mode (STATUSEVST).

The #STDLY1 corresponds to a time period from the EV request (request for the fuel cut operation) to the beginning of the fuel cut operation (from time t0 to time t1 in FIG. 14), and the corresponding status regarding the control pre-operation for starting the EV cruise mode is referred to as STFCPRE.

The #STDLY2 corresponds to a time period from the beginning of the fuel cut operation to the completion of the fuel cut operation for all of the cylinders (from time t1 to time t2 in FIG. 14), and the corresponding status regarding the control pre-operation for starting the EV cruise mode is referred to as STFC.

The #STDLY3 corresponds to a time period from the completion of the fuel cut operation for all of the cylinders to the command for the cylinder deactivation (from time t2 to time t3 in FIG. 14), and the corresponding status regarding the control pre-operation for starting the EV cruise mode is referred to as STFCWT.

The #STDLY4 corresponds to a time period from the command for the cylinder deactivation to the beginning of the cylinder deactivation (from time t3 to time t4 in FIG. 14), and the corresponding status regarding the control pre-operation for starting the EV cruise mode is referred to as STKYTPRE.

The #STDLY5 corresponds to a time period from the beginning of the cylinder deactivation to the completion of the cylinder deactivation for all of the cylinders (from time t4 to time t5 in FIG. 14), and the corresponding status regarding the control pre-operation for starting the EV cruise mode is referred to as STKYT.

The status regarding the control pre-operation for starting the EV cruise mode after the all-cylinder deactivation is completed (after time t5 in FIG. 14) is referred to as STEV.

A predetermined value is subtracted from the TDC counter TDCEVST for the control pre-operation for starting the EV cruise mode every time the engine 2 passes

through the top dead center (TDC).

[0067]

In step S305, it is determined how far the control pre-operation for starting the EV cruise mode has been executed based on the value of the TDC counter TDCEVST for the control pre-operation for starting the EV cruise mode, and the operation proceeds to step S306, in which it is determined whether the current status of the control pre-operation for starting the EV cruise mode is a state before the cylinder deactivation command is made (either one of STFCPRE, STFC, and STFCWT) or is a state after the cylinder deactivation command is made (either one of STKYTPRE, STKYT, and STEV). When it is determined that the current status of the control pre-operation for starting the EV cruise mode is a state before the cylinder deactivation command is made (either one of STFCPRE, STFC, and STFCWT), the operation proceeds to step S307, in contrast, when it is determined that the current status of the control pre-operation for starting the EV cruise mode is a state after the cylinder deactivation command is made (either one of STKYTPRE, STKYT, and STEV), the operation proceeds to step S309.

[0068]

In step S307, a value, which is obtained by adding the engine friction in the all-cylinder operation state ENGFRIC1 retrieved in step S101 in the main control routine of the EV mode to the desired output power PWRRQ retrieved in step S201 in the control operation for determination of request for the EV cruise mode, is set to the desired motor output power TAREVPWR. In this case, because the cylinder deactivation operation is not requested to the engine 2, the operation proceeds to step S308, in which a cylinder deactivation request flag F_KYUTO is set to be "0".

In contrast, in step S309, a value, which is obtained by adding the engine friction in the all-cylinder deactivation state ENGFRIC2 retrieved in step S102 in the main control routine of the EV mode to the desired output power PWRRQ retrieved in step S201 in the control operation for determination of request for the EV cruise mode, is set to the desired motor output power TAREVPWR. In this case, because the cylinder deactivation operation is requested to the engine 2, the operation proceeds to step S310, in which a cylinder deactivation request flag F_KYUTO is set to be "1".

[0069]

After executing step S308 or S310, the operation proceeds to step S311, in which it is determined which one is the current status of the control pre-operation for

starting the EV cruise mode, STFCPRE, STFC, STFCWT, STKYTPRE, STKYT, or STEV.

When it is determined in step S311 that the current status of the control pre-operation for starting the EV cruise mode is STFCPRE, the operation proceeds to step S312, in which the calculated final motor output power CMDEVPWR is set to be PREVPWR, i.e., CMDEVPWR=PREVPWR. The initial value of PREVPWR is "0".

[0070]

When it is determined in step S311 that the current status of the control pre-operation for starting the EV cruise mode is STFC, the operation proceeds to step S313, in which a value, which is obtained by adding, the quotient, which is obtained by dividing a value obtained by subtracting the calculated final motor output power CMDEVPWR in the immediately previous routine from the desired motor output power TAREVPWR by remaining #STDLY2, to the calculated final motor output power CMDEVPWR in the immediately previous routine, is set to the calculated final motor output power CMDEVPWR in this routine, i.e., CMDEVPWR=CMDEVPWR+{(TAREVPWR-CMDEVPWR)/#STDLY2}. In this case, TAREVPWR is "PWRRQ+ENGFRIC1" calculated in step S307.

In the above equation, #STDLY2 is #STDLY2 remaining at the present time. By setting the calculated final motor output power CMDEVPWR as explained above, the output power of the motor-generator 3 is gradually increased stepwise in the STFC period as shown in FIG. 14.

[0071]

When it is determined in step S311 that the current status of the control pre-operation for starting the EV cruise mode is STFCWT, the operation proceeds to step S314, in which TAREVPWR is set to the calculated final motor output power CMDEVPWR. In this case, TAREVPWR is also "PWRRQ+ENGFRIC1" calculated in step S307.

When it is determined in step S311 that the current status of the control pre-operation for starting the EV cruise mode is STKYTPRE, the status in the immediately previous routine is maintained.

[0072]

When it is determined in step S311 that the current status of the control pre-operation for starting the EV cruise mode is STKYT, the operation proceeds to step

S315, in which a value, which is obtained by adding, the quotient, which is obtained by dividing a value obtained by subtracting the calculated final motor output power CMDEVPWR in the immediately previous routine from the desired motor output power TAREVPWR by TDCEVST (i.e., remaining #STDLY5), to the calculated final motor output power CMDEVPWR in the immediately previous routine, is set to the calculated final motor output power CMDEVPWR in this routine, i.e., CMDEVPWR=CMDEVPWR+{(TAREVPWR-CMDEVPWR)/TDCEVST}. In this case, TAREVPWR is "PWRRQ+ENGFRIC2" calculated in step S309.

By setting the calculated final motor output power CMDEVPWR as explained above, the output power of the motor-generator 3 is gradually decreased stepwise in the STKYT period as shown in FIG. 14.

[0073]

When it is determined in step S311 that the current status of the control pre-operation for starting the EV cruise mode is STEV, the operation proceeds to step S317, in which TAREVPWR is set to the calculated final motor output power CMDEVPWR. In this case, TAREVPWR is also "PWRRQ+ENGFRIC2" calculated in step S309.

After executing one of the control operations in steps S312, S313, S314, and S315, or when it is determined in step S311 that the current status of the control pre-operation for starting the EV cruise mode is STKYTPRE, the operation proceeds to step S316, in which a motor cruise mode request flag F_EV is set to be "1", and then the control operation in this routine is terminated.

When the motor cruise mode request flag F_EV is "0", the control pre-operation for starting the EV cruise mode is being executed, and when the motor cruise mode request flag F_EV is "1", the control pre-operation for starting the EV cruise mode is finished. After the flag F_EV becomes "1", the operation proceeds to the control operation for the motor cruise mode in step S107 in the main control routine of the EV mode shown in FIG. 5.

[0074]

<Control pre-operation for finishing the EV cruise mode>

Next, the control pre-operation for finishing the EV cruise mode in step S108 in the main control routine of the EV mode will be explained with reference to the flowcharts shown in FIGS. 15 and 16.

In step S401, it is determined whether the current status is in the motor cruise mode. When the result of the determination in step S401 is "NO", the operation proceeds to step S402, in which the control pre-operation for finishing the EV cruise mode is executed depending on the current status. More specifically, when the vehicle is in a deceleration state, the control pre-operation for finishing the EV cruise mode, which corresponds to the deceleration operation after the motor cruise mode shown in FIG. 4, is executed, and when the vehicle is in an acceleration state, the control pre-operation for finishing the EV cruise mode for immediately switching to the engine cruise mode is executed. Furthermore, the operation proceeds from step S402 to step S402a, in which the fuel cut request flag F_FCREQ is set to be "0", the motor cruise mode request flag F_EV is set to be "0", and the calculated final motor output power CMDEVPWR is set to be "0", and then the control operation in this routine is terminated.

[0075]

When the result of the determination in step S401 is "YES" (i.e., in the motor cruise mode), the operation proceeds to step S403, in which it is determined whether the result of the control operation for determining current status regarding the EV cruise mode in step S105 in the immediately previous main control routine of the EV mode is "the control pre-operation for finishing the EV cruise mode" (i.e., whether EVSTATUS=END). When the result of the determination in step S403 is "NO" (the immediately previous status regarding the EV cruise mode is not the control pre-operation for finishing the EV cruise mode), i.e., this routine is the first-time execution of the control pre-operation for finishing the EV cruise mode, the operation proceeds to step S404. In contrast, when the result of the determination in step S403 is "YES" (the immediately previous status regarding the EV cruise mode is the control pre-operation for finishing the EV cruise mode), the operation proceeds to step S405.

[0076]

In step S404, a TDC counter TDCEVEND for the control pre-operation for finishing the EV cruise mode is set to be an initial value "#ENDDLY1+#ENDDLY2+#ENDDLY3+#ENDDLY4+#ENDDLY5", i.e., TDCEVEND=#ENDDLY1+#ENDDLY2+#ENDDLY3+#ENDDLY4+#ENDDLY5.

Then, the operation proceeds to step S405.

[0077]

FIG. 17 is a timing chart showing a calculated final motor output power CMDEVPWR in the control pre-operation for finishing the EV cruise mode, and more specifically, FIG. 17 shows relationships among the CMDEVPWR, the ENDDLYs, and the status regarding the control pre-operation for finishing the EV cruise mode (STATUSEVEND).

The #ENDDLY1 corresponds to a time period from the request for recovery from the cylinder deactivation operation (request for the engine cruise mode) to the beginning of the recovery from the cylinder deactivation operation (from time t0 to time t1 in FIG. 17), and the corresponding status regarding the control pre-operation for finishing the EV cruise mode is referred to as STKYTENDWT.

The #ENDDLY2 corresponds to a time period from the beginning of the recovery from the cylinder deactivation operation to the completion of the recovery from the cylinder deactivation operation for all of the cylinders (from time t1 to time t2 in FIG. 17), and the corresponding status regarding the control pre-operation for finishing the EV cruise mode is referred to as STKYTEND.

The #ENDDLY3 corresponds to a time period from the completion of the recovery from the cylinder deactivation operation for all of the cylinders to the request for the recovery operation from F/C (from time t2 to time t3 in FIG. 17), and the corresponding status regarding the control pre-operation for finishing the EV cruise mode is referred to as STINJWT.

The #STDLY4 corresponds to a time period from the request for the recovery operation from F/C to the beginning of the recovery operation from F/C (from time t3 to time t4 in FIG. 17), and the corresponding status regarding the control pre-operation for finishing the EV cruise mode is referred to as STINJPRE.

The #ENDDLY5 corresponds to a time period from the beginning of the recovery operation from F/C to the completion of the the recovery operation from F/C for all of the cylinders (from time t4 to time t5 in FIG. 17), and the corresponding status regarding the control pre-operation for finishing the EV cruise mode is referred to as STINJ.

The status regarding the control pre-operation for finishing the EV cruise mode after the recovery operation from F/C for all of the cylinders is completed (after time t5 in FIG. 17) is referred to as STEND.

A predetermined value is subtracted from the TDC counter TDCEVEND for the

control pre-operation for finishing the EV cruise mode every time the engine 2 passes through the top dead center (TDC).

[0078]

In step S405, it is determined how far the control pre-operation for finishing the EV cruise mode has been proceeded based on the value of the TDC counter TDCEVEND for the control pre-operation for finishing the EV cruise mode, and the operation proceeds to step S406, in which it is determined which one is the current status of the control pre-operation for finishing the EV cruise mode, STKYTENDWT, STKYTEND, STINJWT, STINJPRE, STINJ, or STEND.

[0079]

When it is determined in step S406 that the current status of the control pre-operation for finishing the EV cruise mode is STKYTENDWT, the operation proceeds to step S407, in which the fuel cut request flag F_FCREQ is set to be "1", and the motor cruise mode request flag F_EV is set to be "1". Then, the operation proceeds from step S407 to step S408, in which a value, which is obtained by adding the engine friction in the all-cylinder deactivation state ENGFRIC2 retrieved in step S102 in the main control routine of the EV mode to the desired output power PWRRQ retrieved in step S201 in the control operation for determination of request for the EV cruise mode, is set to the desired motor output power TAREVPWR, and this TAREVPWR is set to the calculated final motor output power CMDEVPWR, i.e., CMDEVPWR=TAREVPWR=(PWRRQ+ENGFRIC2), and then the control operation in this routine is terminated.

[0080]

When it is determined in step S406 that the current status of the control pre-operation for finishing the EV cruise mode is STKYTEND, the operation proceeds to step S409, in which the fuel cut request flag F_FCREQ is set to be "1", and the motor cruise mode request flag F_EV is set to be "1". Then, the operation proceeds from step S409 to step S410, in which desired motor output power TAREVPWR and the calculated final motor output power CMDEVPWR are set, and then the control operation in this routine is terminated. More specifically, a value, which is obtained by adding the engine friction in the all-cylinder operation state ENGFRIC1 retrieved in step S102 in the main control routine of the EV mode to the desired output power PWRRQ retrieved in step S201 in the control operation for determination of request for the EV cruise mode, is

set to the desired motor output power TAREVPWR. In addition, a value, which is obtained by adding, the quotient, which is obtained by dividing a value obtained by subtracting the calculated final motor output power CMDEVPWR in the immediately previous routine from the desired motor output power TAREVPWR by remaining #ENDDLY2, to the calculated final motor output power CMDEVPWR in the immediately previous routine, is set to the calculated final motor output power CMDEVPWR in this routine, i.e., TAREVPWR=PWRRQ+ENGFRIC1, and CMDEVPWR=CMDEVPWR+{(TAREVPWR-CMDEVPWR)/#ENDDLY2}.

In the above equation, #ENDDLY2 is #ENDDLY2 remaining at the present time. By setting the calculated final motor output power CMDEVPWR as explained above, the output power of the motor-generator 3 is gradually increased stepwise in the STKYTEND period as shown in FIG. 17.

[0081]

When it is determined in step S406 that the current status of the control pre-operation for finishing the EV cruise mode is STINJWT, the operation proceeds to step S411, in which the fuel cut request flag F_FCREQ is set to be "1", and the motor cruise mode request flag F_EV is set to be "1". Then, the operation proceeds from step S411 to step S412, in which a value, which is obtained by adding the engine friction in the all-cylinder operation state ENGFRIC1 retrieved in step S101 in the main control routine of the EV mode to the desired output power PWRRQ retrieved in step S201 in the control operation for determination of request for the EV cruise mode, is set to the desired motor output power TAREVPWR, and this TAREVPWR is set to the calculated final motor output power CMDEVPWR, i.e., CMDEVPWR=TAREVPWR=(PWRRQ+ENGFRIC1), and then the control operation in this routine is terminated.

[0082]

When it is determined in step S406 that the current status of the control pre-operation for finishing the EV cruise mode is STINJPRE, the operation proceeds to step S413, in which the fuel cut request flag F_FCREQ is set to be "0", and the motor cruise mode request flag F_EV is set to be "1", and then the control operation in this routine is terminated. Accordingly, in the STINJPRE period, the calculated final motor output power CMDEVPWR is maintained to be the value in the previous routine, and because the flag F_FCREQ is set to be "0", the recovery operation from F/C is requested.

[0083]

When it is determined in step S406 that the current status of the control pre-operation for finishing the EV cruise mode is STINJ, the operation proceeds to step S414, in which the fuel cut request flag F_FCREQ is set to be "0", and the motor cruise mode request flag F_EV is set to be "1". Then, the operation proceeds from step S414 to step S415, in which a value, which is obtained by adding, the quotient, which is obtained by dividing a value obtained by subtracting the calculated final motor output power CMDEVPWR in the immediately previous routine from the desired motor output power TAREVPWR by TDCEVEND (i.e., remaining #ENDDLY5), to the calculated final motor output power CMDEVPWR in the immediately previous routine, is set to the calculated final motor output power CMDEVPWR in this routine, i.e., TAREVPWR=0, and CMDEVPWR=CMDEVPWR+{(TAREVPWR-CMDEVPWR)/TDCEVEND}, and then the control operation in this routine is terminated.

By setting the calculated final motor output power CMDEVPWR as explained above, the output power of the motor-generator 3 is gradually decreased stepwise in the STINJ period, and finally becomes "0" as shown in FIG. 17.

[0084]

When it is determined in step S406 that the current status of the control pre-operation for finishing the EV cruise mode is STEND, the operation proceeds to step S416, in which the fuel cut request flag F_FCREQ is set to be "0", and the motor cruise mode request flag F_EV is set to be "0", and then the operation proceeds to step S417, in which the calculated final motor output power CMDEVPWR is set to be "0", and then the control operation in this routine is terminated. At this time, the switching operation from the motor cruise mode to the engine cruise mode is completed.

[0085]

<Control operation for calculating the starting clutch oil pressure correction coefficient>

Next, the control operation for calculating the starting clutch oil pressure correction coefficient will be explained with reference to the flowcharts shown in FIGS. 18 to 20.

The flowcharts shown in FIGS. 18 to 20 show the control routine for calculating the starting clutch oil pressure correction coefficient, which is repeatedly and periodically executed by the ECU 19.

In step S501, it is determined whether the value of a flag F_EVST, which

indicates that correction of the starting clutch oil pressure at the beginning of the motor cruise mode is executed, is “0” or “1”. When it is determined in step S501 that the value of the flag F_EVST is “1” (i.e., correction of the starting clutch oil pressure at the beginning of the motor cruise mode is being executed), the operation proceeds to step S502, in which it is determined whether the value of the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode is 1.0.

When the result of the determination in step S502 is “YES” (i.e., KCLEV=1.0), the operation proceeds to step S503, in which the flag F_EVST is set to be “0”.

[0086]

In contrast, when it is determined in step S501 that the value of the flag F_EVST is “0” (i.e., correction of the starting clutch oil pressure at the beginning of the motor cruise mode is not executed), and the result of the determination in step S502 is “NO” (i.e., KCLEV≠1.0), and the operation in step S503 is executed, the operation proceeds to step S504, in which it is determined whether the value of a flag F_EVEND, which indicates that correction of the starting clutch oil pressure at the end of the motor cruise mode is executed, is “0” or “1”.

When it is determined in step S504 that the value of the flag F_EVEND is “1” (i.e., correction of the starting clutch oil pressure at the end of the motor cruise mode is being executed), the operation proceeds to step S505, in which it is determined whether the value of the starting clutch oil pressure correction coefficient KCLENG at the end of the motor cruise mode is 1.0.

When the result of the determination in step S505 is “YES” (i.e., KCLENG=1.0), the operation proceeds to step S506, in which the flag F_EVEND is set to be “0”.

[0087]

In contrast, when it is determined in step S504 that the value of the flag F_EVEND is “0” (i.e., correction of the starting clutch oil pressure at the beginning of the motor cruise mode is not executed), and the result of the determination in step S505 is “NO” (i.e., KCLENG≠1.0), and the operation in step S506 is executed, the operation proceeds to step S507.

In step S507, it is determined whether the current motor cruise mode request flag F_EV is “1”, and whether the previous motor cruise mode request flag F_EVOLD is “0”. In other words, it is determined whether the motor cruise mode request flag F_EV becomes “1” in this routine.

When the result of the determination in step S507 is "YES" (i.e., the motor cruise mode request flag F_EV becomes "1" in this routine), the operation proceeds to step S508, in which an oil pressure maintaining timer TMEV at the beginning of the motor cruise mode is set to be an initial value TMEVST (corresponding to time between t0 and t5 in the time chart shown in FIG. 2), and then the operation proceeds to step S509, in which the flag F_EVST, which indicates that correction of the starting clutch oil pressure at the beginning of the motor cruise mode is executed, is set to be "1", and the flag F_EVEND, which indicates that correction of the starting clutch oil pressure at the end of the motor cruise mode is executed, is set to be "0".

[0088]

In contrast, when the result of the determination in step S507 is "NO" (i.e., the motor cruise mode request flag F_EV was also "1" in the previous routine), the operation proceeds to step S510, in which it is determined whether the current motor cruise mode request flag F_EV is "0", and whether the previous motor cruise mode request flag F_EVOLD is "1".

When the result of the determination in step S510 is "YES" (i.e., the motor cruise mode request flag F_EV becomes "1" in this routine), the operation proceeds to step S511, in which an oil pressure maintaining timer TMENG at the end of the motor cruise mode is set to be an initial value TMEVEND (corresponding to time between t0 and t3 in the time chart shown in FIG. 3), and then the operation proceeds to step S512, in which the flag F_EVEND, which indicates that correction of the starting clutch oil pressure at the end of the motor cruise mode is executed, is set to be "1", and the flag F_EVST, which indicates that correction of the starting clutch oil pressure at the beginning of the motor cruise mode is executed, is set to be "0".

In the timing chart shown in FIG. 3, the end point of the TMEVEND, which is used as the initial value of TMENG, coincides with a point at which the recovery operation from F/C begins; however, these two points do not have to coincide with each other.

[0089]

In contrast, when the result of the determination in step S510 is "NO" (i.e., the motor cruise mode request flag F_EV was also "0" in the previous routine), after the operation in step S509 is executed, and after the operation in step S512 is executed, the operation proceeds to step S513.

In step S513, it is determined whether the flag F_EVST is "1". When the result of the determination is "YES" (F_EVST=1), the operation proceeds to step S514, and when the result of the determination is "NO" (F_EVST≠1), the operation proceeds to step S525.

[0090]

In step S514, a value obtained by adding a predetermined F/C recovery revolution rate additional term DNE to the F/C recovery revolution rate NELOW in the current drive state is set to an engine revolution rate lower reference value NELOW1.

[0091]

Next, the operation proceeds from step S514 to S515, in which it is determined whether the current engine revolution rate NE is less than or equal to the engine revolution rate lower reference value NELOW1. When the result of the determination in step S515 is "NO" (i.e., NE>NELOW), the operation proceeds to step S519. In contrast, when the result of the determination in step S510 is "YES" (i.e., NE≤NELOW), the operation proceeds to step S516, in which a value, which is obtained by adding an oil pressure correction coefficient additional term DKCLEV2 for the reduced engine revolution rate at the beginning of the motor cruise mode to the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode in the immediately previous routine, is set to the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode in the present routine, i.e., KCLEV=KCLEV+DKCLEV2.

[0092]

Next, the operation proceeds from step S516 to step S517, in which it is determined whether the KCLEV is greater than or equal to "1.0". When the result of the determination in step S517 is "NO" (i.e., KCLEV<1.0), the operation proceeds to step S519. In contrast, when the result of the determination in step S517 is "YES" (i.e., KCLEV≥1.0), the operation proceeds to step S518, in which KCLEV is set to be "1.0", and the oil pressure maintaining timer TMEV at the beginning of the motor cruise mode is set to be "0", and then the operation proceeds to step S519.

[0093]

In step S519, it is determined whether the TMEV is "0". When the result of the determination in step S519 is "NO" (i.e., TMEV≠0), the operation proceeds to step S520, in which it is determined whether the KCLEV is "1.0". When the result of the

determination in step S520 is "NO" (i.e., KCLEV≠0), the operation proceeds to step S526. In contrast, when the result of the determination in step S520 is "YES" (i.e., KCLEV=0), the operation proceeds to step S521, in which an initial value KCLEV1 for the starting clutch oil pressure correction coefficient at the beginning of the motor cruise mode is set to the KCLEV, and the operation proceeds to step S526.

[0094]

In contrast, when the result of the determination in step S519 is "YES" (i.e., TMEV=0), the operation proceeds to step S522, in which a value, which is obtained by adding an oil pressure correction coefficient additional term DKCLEV1 at the beginning of the motor cruise mode to the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode in the immediately previous routine, is set to the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode in the present routine, i.e., KCLEV=KCLEV+DKCLEV1.

Next, the operation proceeds from step S522 to step S523, in which it is determined whether the KCLEV is greater than "1.0". When the result of the determination in step S523 is "NO" (i.e., KCLEV≤1.0), the operation proceeds to step S526.

In contrast, when the result of the determination in step S523 is "YES" (i.e., KCLEV>1.0), the operation proceeds to step S524, in which the KCLEV is set to be "1.0", and the operation proceeds to step S526.

[0095]

When the operation proceeded to step S525 after it is determined to be "NO" (F_EVST≠1) in step S513, the KCLEV is set to be "1.0" in step S525, and the operation proceeds to step S526.

In step S526, it is determined whether the F_EVEND is "1". When the result of the determination is "NO" (i.e., F_EVEND=0), the operation proceeds to step S527, in which the KCLENG is set to be "1.0", and the control operation in this routine is terminated.

[0096]

In contrast, when the result of the determination in step S526 is "YES" (i.e., F_EVEND=1), the operation proceeds to step S528.

In step S528, a value, which is obtained by adding the predetermined F/C recovery revolution rate additional term DNE to the F/C recovery revolution rate

NELOW in the current drive state, is set to the engine revolution rate lower reference value NELOW1.

[0097]

Next, the operation proceeds from step S528 to S529, in which it is determined whether the current engine revolution rate NE is less than or equal to the engine revolution rate lower reference value NELOW1. When the result of the determination in step S529 is "NO" (i.e., NE>NELOW1), the operation proceeds to step S533. In contrast, when the result of the determination in step S510 is "YES" (i.e., NE≤NELOW1), the operation proceeds to step S530, in which a value, which is obtained by adding an oil pressure correction coefficient additional term DKCLENG2 for the reduced engine revolution rate at the end of the motor cruise mode to the starting clutch oil pressure correction coefficient KCLENG at the end of the motor cruise mode in the immediately previous routine, is set to the starting clutch oil pressure correction coefficient KCLENG at the end of the motor cruise mode in the present routine, i.e., KCLENG=KCLENG+DKCLENG2.

[0098]

Next, the operation proceeds from step S530 to step S531, in which it is determined whether the KCLENG is greater than or equal to "1.0". When the result of the determination in step S531 is "NO" (i.e., KCLENG<1.0), the operation proceeds to step S533. In contrast, when the result of the determination in step S531 is "YES" (i.e., KCLENG≥1.0), the operation proceeds to step S532, in which KCLENG is set to be "1.0", and the oil pressure maintaining timer TMENG at the end of the motor cruise mode is set to be "0", and then the operation proceeds to step S533.

[0099]

In step S533, it is determined whether the TMENG is "0". When the result of the determination in step S533 is "NO" (i.e., TMENG≠0), the operation proceeds to step S534, in which it is determined whether the KCLENG is "1.0". When the result of the determination in step S534 is "NO" (i.e., KCLENG≠0), the control operation in this routine is terminated. In contrast, when the result of the determination in step S534 is "YES" (i.e., KCLENG=0), the operation proceeds to step S535, in which an initial value KCLENG1 for the starting clutch oil pressure correction coefficient at the end of the motor cruise mode is set to the KCLENG, and the control operation in this routine is terminated.

[0100]

When the result of the determination in step S533 is "YES" (i.e., TMENG=0), the operation proceeds to step S536, in which a value, which is obtained by adding an oil pressure correction coefficient DKCLENG1 at the end of the motor cruise mode to KCLENG in the immediately previous routine, is set to KCLENG in the present routine, i.e., KCLENG=KCLENG+DKCLENG1.

Next, the operation proceeds from step S536 to step S537, in which it is determined whether the KCLENG is greater than "1.0". When the result of the determination in step S537 is "NO" (i.e., KCLENG≤1.0), the control operation in this routine is terminated.

In contrast, when the result of the determination in step S537 is "YES" (i.e., KCLENG>1.0), the operation proceeds to step S538, in which KCLENG is set to be "1.0", and then the control operation in this routine is terminated.

[0101]

Note that the desired oil pressure for the starting clutch CLCMD is calculated by multiplying the previous desired oil pressure for the starting clutch CLCMD by the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode, and by the starting clutch oil pressure correction coefficient KCLENG at the end of the motor cruise mode, i.e., CLCMD=(CLCMD)×(KCLEV)×(KCLENG).

[0102]

Next, a supplementary explanation for the case, in which the result of the determination in step S507 is "YES", and correction of the starting clutch oil pressure at the beginning of the motor cruise mode is started, will be given below.

When it is determined "YES" in step S507, and correction of the starting clutch oil pressure at the beginning of the motor cruise mode is started, it is determined "YES" in step S513 because the F_EVST is set to be "1", and the F_EVEND is set to be "0" in step S509. Because the engine revolution rate NE at a point immediately after starting of correction of clutch oil pressure at the beginning of the motor cruise mode is greater than the engine revolution rate lower reference value NELOW1, and the oil pressure maintaining timer TMEV at the beginning of the motor cruise mode is not "0", it is determined "NO" in step S515 in the first control routine, and it is determined "NO" in step S519, and then the operation proceeds to step S520. Because the KCLEV before the first control routine is "1.0", it is determined "YES" in step S520 in the first control

routine, and KCLEV1 is set to the KCLEV in step S521. Moreover, because it is determined "NO" in step S526, the KCLENG is set to be "1.0" in step S527. As a result, the engagement decreasing control operation for the starting clutch 12 is executed immediately after starting of correction of clutch oil pressure at the beginning of the motor cruise mode (at time t0 in the timing chart shown in FIG. 2).

[0103]

After this operation, the F_EVST is maintained to be "1", and the result of the determination in step S513 is maintained to be "YES" until it is determined "YES" in step S502 (i.e., KCLEV=1.0).

If the engine revolution rate NE decreases to a level below the NELOW between when correction of the clutch oil pressure at the beginning of the motor cruise mode is started and when the TMEV becomes "0", it is determined "YES" in step S515, and in step S516, the KCLEV is corrected so as to be increased by the DKCLEV2 which is a correction term. In other words, when the engine revolution rate NE decreases to a level below the NELOW during the clutch relaxation control operation for the starting clutch 12, an engagement increasing control operation, in which the engagement degree of the starting clutch 12 is forced to increase, is executed (corresponding to time t0 to t5 in the timing chart shown in FIG. 2). When the KCLEV becomes equal to or greater than "1.0" during the engagement increasing control operation, the result of the determination in step S517 becomes "YES", the KCLEV is set to be "1.0" which is the upper limit value, and the TMEV is set to be "0" in step S518.

[0104]

The result of the determination in step S519 is "NO" until the TMEV becomes "0", and it is determined "NO" in step S520, and then the operation proceeds to step S526 until the KCLEV becomes "1.0".

When the TMEV becomes "0", the result of the determination in step S519 becomes "YES", and in step S522, the KCLEV is corrected so as to be increased by the DKCLEV1 which is a correction term (corresponding to time t5 to t7 in the timing chart shown in FIG. 2). The result of the determination in step S523 is "NO" and the operation proceeds to step S526 until the KCLEV becomes equal to or greater than "1.0". When the KCLEV becomes equal to or greater than "1.0", the result of the determination in step S523 becomes "YES", the KCLEV is set to be "1.0", in step S524, which is the upper limit value (corresponding to time t7 or after in the timing chart shown in FIG. 2),

and the operation proceeds to step S526.

[0105]

In other words, regardless of whether or not the KCLEV is corrected so as to be increased in step S516, the KCLEV is corrected so as to be increased in step S522. However, when the KCLEV is set to be "1.0" in step S518, the increasing correction of the KCLEV in step S522 substantially has no effect because the KCLEV is greater than "1.0" when the KCLEV is further increased in step S522, and thus the KCLEV is maintained to be "1.0" in step S524.

[0106]

The correction term DKCLEV2 for the increasing correction of the KCLEV in step S516 (i.e., an increment of increase in the engagement increasing control operation) is set to be less than the correction term DKCLEV1 for the increasing correction of the KCLEV in step S522 (i.e., an increment of increase in the engagement recovery control operation), i.e., DKCLEV2<DKCLEV1. This is because the purpose of the increasing correction of the KCLEV in step S516 is to just slightly increase the engine revolution rate, and for this purpose, a slight increase in the clutch oil pressure is sufficient. By this setting, the engine revolution rate can be increased without degrading effects of the clutch relaxation control operation.

[0107]

Next, the case, in which correction of the starting clutch oil pressure at the end of the motor cruise mode is started after it is determined "YES" in step S510, will be explained below.

When it is determined "YES" in step S510, and correction of the starting clutch oil pressure at the end of the motor cruise mode is started, because the F_EVEND is set to be "1", and the F_EVST is set to be "0" in step S512, it is determined "NO" in step S513, the KCLEV is set to be "1.0" in step S525, and it is determined "YES" in step S526.

Because the engine revolution rate NE at a point immediately after starting of correction of clutch oil pressure at the end of the motor cruise mode is greater than the engine revolution rate lower reference value NELOW1, and the oil pressure maintaining timer TMENG at the end of the motor cruise mode is not "0", it is determined "NO" in step S529 in the first control routine, and it is determined "NO" in step S533, and then the operation proceeds to step S534. Because the KCLEV before the first control

routine is "1.0", it is determined "YES" in step S534 in the first control routine, and KCLENG1 is set to the KCLENG in step S535. As a result, the engagement decreasing control operation for the starting clutch 12 is executed immediately after starting of correction of clutch oil pressure at the end of the motor cruise mode (at time t0 in the timing chart shown in FIG. 3).

[0108]

After this operation, the F_EVEND is maintained to be "1", and the result of the determination in step S526 is maintained to be "YES" until it is determined "YES" in step S505 (i.e., KCLENG=1.0).

If the engine revolution rate NE decreases to a level below the NELOW between when correction of the clutch oil pressure at the end of the motor cruise mode is started and when the TMEV becomes "0", it is determined "YES" in step S529, and in step S530, the KCLENG is corrected so as to be increased by the DKCLENG2 which is a correction term. In other words, when the engine revolution rate NE decreases to a level below the NELOW during the clutch relaxation control operation for the starting clutch 12, an engagement increasing control operation, in which the engagement degree of the starting clutch 12 is forced to increase, is executed (corresponding to time t0 to t3 in the timing chart shown in FIG. 2). When the KCLENG becomes equal to or greater than "1.0" during the engagement increasing control operation, the result of the determination in step S531 becomes "YES", the KCLENG is set to be "1.0" which is the upper limit value, and the TMENG is set to be "0" in step S532.

[0109]

The result of the determination in step S533 is "NO" until the TMENG becomes "0", and it is determined "NO" in step S534 until the KCLENG becomes "1.0".

When the TMENG becomes "0", the result of the determination in step S533 becomes "YES", and in step S536, the KCLENG is corrected so as to be increased by the DKCLENG1 which is a correction term (corresponding to time t3 to t5 in the timing chart shown in FIG. 3). The result of the determination in step S537 is "NO" until the KCLENG becomes equal to or greater than "1.0". When the KCLENG becomes equal to or greater than "1.0", the result of the determination in step S537 becomes "YES", and the KCLEV is set to be "1.0", in step S538, which is the upper limit value (corresponding to time t5 or after in the timing chart shown in FIG. 3), and the operation proceeds to step S526.

[0110]

In other words, regardless of whether or not the KCLENG is corrected so as to be increased in step S530, the KCLENG is corrected so as to be increased in step S536. However, when the KCLENG is set to be "1.0" in step S532, the increasing correction of the KCLENG in step S536 substantially has no effect because the KCLENG is greater than "1.0" when the KCLENG is further increased in step S536, and thus the KCLENG is maintained to be "1.0" in step S538.

[0111]

The correction term DKCLENG2 for the increasing correction of the KCLENG in step S530 (i.e., an increment of increase in the engagement increasing control operation) is set to be less than the correction term DKCLENG1 for the increasing correction of the KCLENG in step S536 (i.e., an increment of increase in the engagement recovery control operation), i.e., DKCLENG2<DKCLENG1. This is because the purpose of the increasing correction of the KCLENG in step S530 is to just slightly increase the engine revolution rate, and for this purpose, a slight increase in the clutch oil pressure is sufficient. By this setting, the engine revolution rate can be increased without degrading effects of the clutch relaxation control operation.

[0112]

During deceleration after the motor cruise mode, because the F_EV is set to be "0" in step S402a in the control pre-operation for finishing the EV cruise mode shown in FIG. 15, it is determined "YES" in step S510, and correction of the starting clutch oil pressure at the end of the motor cruise mode is executed.

In the above embodiment, the clutch control means is configured by executing the series of the operations from step S501 to step S538.

[0113]

<Second Embodiment>

FIGS. 23 to 25 are flowcharts showing the control operation for calculating the starting clutch oil pressure correction coefficient for the hybrid vehicle of a second embodiment.

In the first embodiment explained above, when the driving mode is switched, the engine revolution rate is maintained above the NELOW by executing the engagement increasing control operation, in which the engagement degree of the starting clutch 12 is forced to increase, when the engine revolution rate is decreased to a level below the

NELOW during the clutch relaxation control operation for the starting clutch 12; however, in the second embodiment, the engine revolution rate is maintained above a predetermined value (e.g., above the NELOW in the first embodiment) by controlling the engagement degree of the starting clutch 12, during the clutch relaxation control operation, depending on the engine revolution rate.

To this end, in the second embodiment, a starting clutch oil pressure correction coefficient KCLV_T at the beginning of the motor cruise mode and a starting clutch oil pressure correction coefficient KCLENG_T at the end of the motor cruise mode, which are required for maintaining the engine revolution rate NE above the NELOW, are determined by experiments, and are stored in a ROM in the ECU 19.

[0114]

FIG. 24 is a graph drawn based on an example of a table that defines the starting clutch oil pressure correction coefficient at the beginning of the motor cruise mode. As shown, the starting clutch oil pressure correction coefficient KCLEV_T at the beginning of the motor cruise mode is set to be great for high engine revolution rate NE, and the KCLEV_T increases in accordance with decrease in the engine revolution rate NE, and is set to "1.0", which is the upper limit value, for the engine revolution rate NE below a predetermined value.

FIG. 25 is a graph drawn based on an example of a table that defines the starting clutch oil pressure correction coefficient at the end of the motor cruise mode. As shown, the starting clutch oil pressure correction coefficient KCLENG_T at the end of the motor cruise mode is set to be great for high engine revolution rate NE, and the KCLENG_T increases in accordance with decrease in the engine revolution rate NE, and is set to "1.0", which is the upper limit value, for the engine revolution rate NE below a predetermined value.

[0115]

Next, the control operation for calculating the starting clutch oil pressure correction coefficient in the second embodiment will be explained with reference to the flowcharts shown in FIGS. 21 to 23.

The series of the control operations from step S601 to step S613 is the same as in the series of the control operations from step S501 to step S513 shown in FIG. 18; therefore, the explanation thereof is omitted here.

When the result of the determination in step S613 is "YES" (i.e., F_EVST=1),

the operation proceeds to step S614, and when the result of the determination is "NO" (i.e., F_EVST≠1), the operation proceeds to step S620.

In step S614, the KCLEV_T is retrieved, depending on the engine revolution rate NE, from the table defining the starting clutch oil pressure correction coefficient at the beginning of the motor cruise mode represented by the graph shown in FIG. 24, and the operation proceeds to step S615, in which the retrieved KCLEV_T is set to the KCLEV, i.e., KCLEV= KCLEV_T.

[0116]

Because the engine revolution rate at a point immediately after starting of correction of clutch oil pressure at the beginning of the motor cruise mode is high, the KCLEV_T is set to be small, and the engagement decreasing control operation for the starting clutch 12 is executed. When the engine revolution rate NE decreases as the engagement degree of the starting clutch 12 is decreased, the KCLEV_T is gradually made greater. As a result, the engagement degree of the starting clutch 12 is controlled so that the engine revolution rate NE is maintained to be greater that the NELOW until the TMEV becomes "0".

[0117]

Next, the operation proceeds from step S615 to step S616, in which it is determined whether the TMEV is "0". When the result of the determination in step S616 is "NO" (i.e., TMEV≠0), the operation proceeds to step S621.

When the result of the determination in step S616 is "YES" (i.e., TMEV=0), the operation proceeds to step S617, in which a value, which is obtained by adding an oil pressure correction coefficient additional term DKCLEV1 at the beginning of the motor cruise mode to the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode in the immediately previous routine, is set to the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode in the present routine, i.e., KCLEV=KCLEV+DKCLEV1.

As a result, the KCLEV is corrected so as to be increased by the DKCLEV1, which is a correction term, after the TMEV becomes "0".

[0118]

Next, the operation proceeds from step S617 to step S618, in which it is determined whether the KCLEV is greater than "1.0". When the result of the determination in step S618 is "NO" (i.e., KCLEV≤1.0), the operation proceeds to step

S621.

In contrast, when the result of the determination in step S618 is "YES" (i.e., KCLEV>1.0), the operation proceeds to step S619, in which KCLEV is set to be "1.0", and the operation proceeds to step S621.

As a result, the KCLEV is continuously corrected so as to be increased by the DKCLEV1, which is a correction term, until the KCLEV becomes "1.0".

[0119]

When the operation proceeded to step S620 after it is determined to be "NO" (F_EVST≠1) in step S613, the KCLEV is set to be "1.0" in step S620, and the operation proceeds to step S621.

In step S621, it is determined whether the F_EVEND is "1". When the result of the determination is "NO" (i.e., F_EVEND=0), the operation proceeds to step S622, in which the KCLENG is set to be "1.0", and the control operation in this routine is terminated.

[0120]

In contrast, when the result of the determination in step S621 is "YES" (i.e., F_EVEND=1), the operation proceeds to step S623.

In step S623, the KCLENG_T is retrieved, depending on the engine revolution rate NE, from the table defining the starting clutch oil pressure correction coefficient at the end of the motor cruise mode represented by the graph shown in FIG. 25, and the operation proceeds to step S624, in which the retrieved KCLENG_T is set to the KCLENG, i.e., KCLENG= KCLENG_T.

[0121]

Because the engine revolution rate NE at a point immediately after starting of correction of clutch oil pressure at the end of the motor cruise mode is high, the KCLENG_T is set to be small, and the engagement decreasing control operation for the starting clutch 12 is executed. When the engine revolution rate NE decreases as the engagement degree of the starting clutch 12 is decreased, the KCLENG_T is gradually made greater. As a result, the engagement degree of the starting clutch 12 is controlled so that the engine revolution rate NE is maintained to be greater that the NELOW until the TMENG becomes "0".

[0122]

Next, the operation proceeds from step S624 to step S625, in which it is

determined whether the TMENG is "0". When the result of the determination in step S625 is "NO" (i.e., TMENG≠0), the control operation in this routine is terminated.

When the result of the determination in step S625 is "YES" (i.e., TMENG=0), the operation proceeds to step S626, in which a value, which is obtained by adding an oil pressure correction coefficient additional term DKCLENG1 at the end of the motor cruise mode to the starting clutch oil pressure correction coefficient KCLENG at the end of the motor cruise mode in the immediately previous routine, is set to the starting clutch oil pressure correction coefficient KCLENG at the end of the motor cruise mode in the present routine, i.e., KCLENG=KCLENG+DKCLENG1.

As a result, the KCLEV is corrected so as to be increased by the DKCLENG1, which is a correction term, after the TMENG becomes "0".

[0123]

Next, the operation proceeds from step S626 to step S627, in which it is determined whether the KCLENG is greater than "1.0". When the result of the determination in step S627 is "NO" (i.e., KCLENG≤1.0), the control operation in this routine is terminated.

In contrast, when the result of the determination in step S627 is "YES" (i.e., KCLENG>1.0), the operation proceeds to step S628, in which KCLENG is set to be "1.0", and the control operation in this routine is terminated.

As a result, the KCLENG is continuously corrected so as to be increased by the DKCLENG1, which is a correction term, until the KCLENG becomes "1.0".

[0124]

Note that the desired oil pressure for the starting clutch CLCMD is calculated by multiplying the previous desired oil pressure for the starting clutch CLCMD by the starting clutch oil pressure correction coefficient KCLEV at the beginning of the motor cruise mode, and by the starting clutch oil pressure correction coefficient KCLENG at the end of the motor cruise mode, i.e., CLCMD=(CLCMD)×(KCLEV)×(KCLENG).

In the second embodiment, the clutch control means is configured by executing the series of the operations from step S601 to step S628.

[0125]

In the second embodiment, as in the first embodiment, the clutch relaxation control operation for the starting clutch 12 can be executed during the switching operation between the driving modes, and the engine revolution rate can be maintained

above the F/C recovery revolution rate.

As a result, a drag feeling due to a fuel cut operation can be reduced when the driving mode of the vehicle is switched from the engine cruise mode to the motor cruise mode, and a combustion initiation jolt due to start of the engine operation can also be reduced when the driving mode of the vehicle is switched from the motor cruise mode to the engine cruise mode; therefore, vehicle behavior is stabilized, and drivability can be improved when the driving mode of the vehicle is switched back and forth between the engine cruise mode and the motor cruise mode.

In addition, because increase in vehicle jolt, which may occur due to decreased engine revolution rate, can be prevented, drivability can be improved. Furthermore, because the engine revolution rate will not reach the F/C recovery revolution rate, unnecessary fuel supply to the engine 2 due to the recovery operation from F/C can be reliably prevented, and fuel efficiency can be improved.

Moreover, because the engagement degree of the starting clutch 12, which is once decreased at the transition from the engine cruise mode to the motor cruise mode, or at the transition from the motor cruise mode to the engine cruise mode, is reliably recovered at completion of the transition of the driving mode, energy loss due to the clutch relaxation control operation can be minimized.

[0126]

For example, in the above embodiments, the transmission is assumed to be a continuously variable transmission; however, the present invention may be applied to a conventional geared transmission. In this case, the clutch means may be a lockup clutch.

[0127]

[Advantageous Effects of the Invention]

As explained above, according to the invention of claim 1, because the motor cruise mode can be effectively used in a driving state in which the engine cannot run with high efficiency, fuel efficiency can be improved. In addition, by executing the clutch relaxation control operation, a drag feeling due to a fuel cut operation can be reduced when the driving mode of the vehicle is switched from the engine cruise mode to the motor cruise mode, and a combustion initiation jolt due to start of the engine operation can also be reduced when the driving mode of the vehicle is switched from the motor cruise mode to the engine cruise mode; therefore, vehicle behavior is stabilized, and

drivability can be improved when the driving mode of the vehicle is switched back and forth between the engine cruise mode and the motor cruise mode.

[0128]

Furthermore, by executing the engagement increasing control operation for the clutch means when the revolution rate of the engine falls below a predetermined value during the clutch relaxation control operation, the engine revolution rate will not decrease further, and the engine revolution rate can be increased; therefore, increase in vehicle jolt, which may occur due to decreased engine revolution rate, can be prevented, and drivability can be improved. In addition, because the engine revolution rate can be prevented from reaching the recovery revolution rate at which fuel supply to the engine is resumed from a fuel cut operation of the engine, and unnecessary fuel supply to the engine can be prevented, and thus fuel efficiency can be improved.

[0129]

According to the invention of claim 2, the engagement degree of the clutch means, which is once decreased by the engagement decreasing control operation, can be reliably recovered at the end of the switching operation between the driving modes; therefore, energy loss due to the clutch relaxation control operation can be minimized.

According to the invention of claim 3, the engine revolution rate can be increased without degrading effects of the clutch relaxation control operation even when the engagement increasing control operation is executed.

According to the invention of claim 4, the engine revolution rate will not reach the F/C recovery revolution rate; therefore, unnecessary fuel supply to the engine can be reliably prevented, and fuel efficiency can be improved.

[0130]

According to the invention of claim 5, the motor cruise mode can be used in a driving state in which the engine cannot run with high efficiency. In addition, by executing the clutch relaxation control operation, a drag feeling due to a fuel cut operation can be reduced when the driving mode of the vehicle is switched from the engine cruise mode to the motor cruise mode, and a combustion initiation jolt due to start of the engine operation can also be reduced when the driving mode of the vehicle is switched from the motor cruise mode to the engine cruise mode; therefore, vehicle behavior is stabilized, and drivability can be improved when the driving mode of the vehicle is switched back and forth between the engine cruise mode and the motor cruise

mode.

[0131]

Furthermore, by controlling the engagement degree of the clutch means depending on the revolution rate of the engine during the clutch relaxation control operation, the engine revolution rate will not decrease to a level below a predetermined value; therefore, increase in vehicle jolt, which may occur due to decreased engine revolution rate, can be prevented, and drivability can be improved. In addition, because the engine revolution rate can be prevented from reaching the recovery revolution rate at which fuel supply to the engine is resumed from a fuel cut operation of the engine, and unnecessary fuel supply to the engine can be prevented, and thus fuel efficiency can be improved.

[0132]

According to the invention of claim 6, because the engagement degree, which is once decreased at the transition from the engine cruise mode to the motor cruise mode, is reliably recovered at completion of the transition of the driving mode, energy loss due to the clutch relaxation control operation can be minimized.

According to the invention of claim 7, in addition to the advantageous effects obtainable by the invention of claims 1 to 6, advantageous effects can be obtained in that the control apparatus can be simplified, and an increase in cost can be avoided since an additional clutch means is not necessary.

[Brief Description of the Drawings]

[FIG. 1] FIG. 1 is a diagram showing the general structure of a driving power transmission system in a first embodiment of a hybrid vehicle according to the present invention.

[FIG. 2] FIG. 2 is a timing chart showing a state of the first embodiment in which the driving mode of the vehicle is switched from an engine cruise mode to a motor cruise mode.

[FIG. 3] FIG. 3 is a timing chart showing a state of the first embodiment in which the driving mode of the vehicle is switched from the motor cruise mode to the engine cruise mode.

[FIG. 4] FIG. 4 is a timing chart showing a state of the first embodiment in which the hybrid vehicle decelerates after the motor cruise mode.

[FIG. 5] FIG. 5 is a flowchart showing a main routine for executing an operation

of a motor cruise mode for the hybrid vehicle of the first embodiment.

[FIG. 6] FIG. 6 is a graph drawn based on a map that defines engine friction values in the hybrid vehicle of the first embodiment in an all-cylinder operation state.

[FIG. 7] FIG. 7 is a graph drawn based on a table that defines engine friction values in the hybrid vehicle of the first embodiment in an all-cylinder deactivation state.

[FIG. 8] FIG. 8 is a flowchart (part 1) showing a control operation for determination of request for the EV cruise mode for the hybrid vehicle of the first embodiment.

[FIG. 9] FIG. 9 is a flowchart (part 2) showing the control operation for determination of request for the EV cruise mode for the hybrid vehicle of the first embodiment.

[FIG. 10] FIG. 10 is a map defining a desired output power for the hybrid vehicle of the first embodiment.

[FIG. 11] FIG. 11 is a graph drawn based on a map that defines a required output power for the motor cruise mode in the hybrid vehicle of the first embodiment in an all-cylinder deactivation state.

[FIG. 12] FIG. 12 is a flowchart (part 1) showing a control pre-operation for starting the EV cruise mode for the hybrid vehicle of the first embodiment.

[FIG. 13] FIG. 13 is a flowchart (part 2) showing the control pre-operation for starting the EV cruise mode for the hybrid vehicle of the first embodiment.

[FIG. 14] FIG. 14 is a timing chart showing a calculated final motor output power in the control pre-operation for starting the EV cruise mode.

[FIG. 15] FIG. 15 is a flowchart (part 1) showing a control pre-operation for finishing the EV cruise mode for the hybrid vehicle of the first embodiment.

[FIG. 16] FIG. 16 is a flowchart (part 2) showing the control pre-operation for finishing the EV cruise mode for the hybrid vehicle of the first embodiment.

[FIG. 17] FIG. 17 is a timing chart showing a calculated final motor output power in the control pre-operation for finishing the EV cruise mode.

[FIG. 18] FIG. 18 is a flowchart (part 1) showing a control operation for calculating the starting clutch oil pressure correction coefficient for the hybrid vehicle of the first embodiment.

[FIG. 19] FIG. 19 is a flowchart (part 2) showing the control operation for calculating the starting clutch oil pressure correction coefficient for the hybrid vehicle of

the first embodiment.

[FIG. 20] FIG. 20 is a flowchart (part 3) showing the control operation for calculating the starting clutch oil pressure correction coefficient for the hybrid vehicle of the first embodiment.

[FIG. 21] FIG. 21 is a flowchart (part 1) showing a control operation for calculating the starting clutch oil pressure correction coefficient for the hybrid vehicle of a second embodiment.

[FIG. 22] FIG. 22 is a flowchart (part 2) showing the control operation for calculating the starting clutch oil pressure correction coefficient for the hybrid vehicle of the second embodiment.

[FIG. 23] FIG. 23 is a flowchart (part 3) showing the control operation for calculating the starting clutch oil pressure correction coefficient for the hybrid vehicle of the second embodiment.

[FIG. 24] FIG. 24 is a graph drawn based on an example of a table that defines the starting clutch oil pressure correction coefficient at the beginning of the motor cruise mode.

[FIG. 25] FIG. 25 is a graph drawn based on an example of a table that defines the starting clutch oil pressure correction coefficient at the end of the motor cruise mode.

[Description of the Reference Symbols]

1: hybrid vehicle

2: engine

3: motor-generator (generatable motor)

12: starting clutch (clutch means)

13a, 13b:axle shaft (output shaft)

S501-S538, S601-S628 (clutch control means)

[Document Type] Abstract

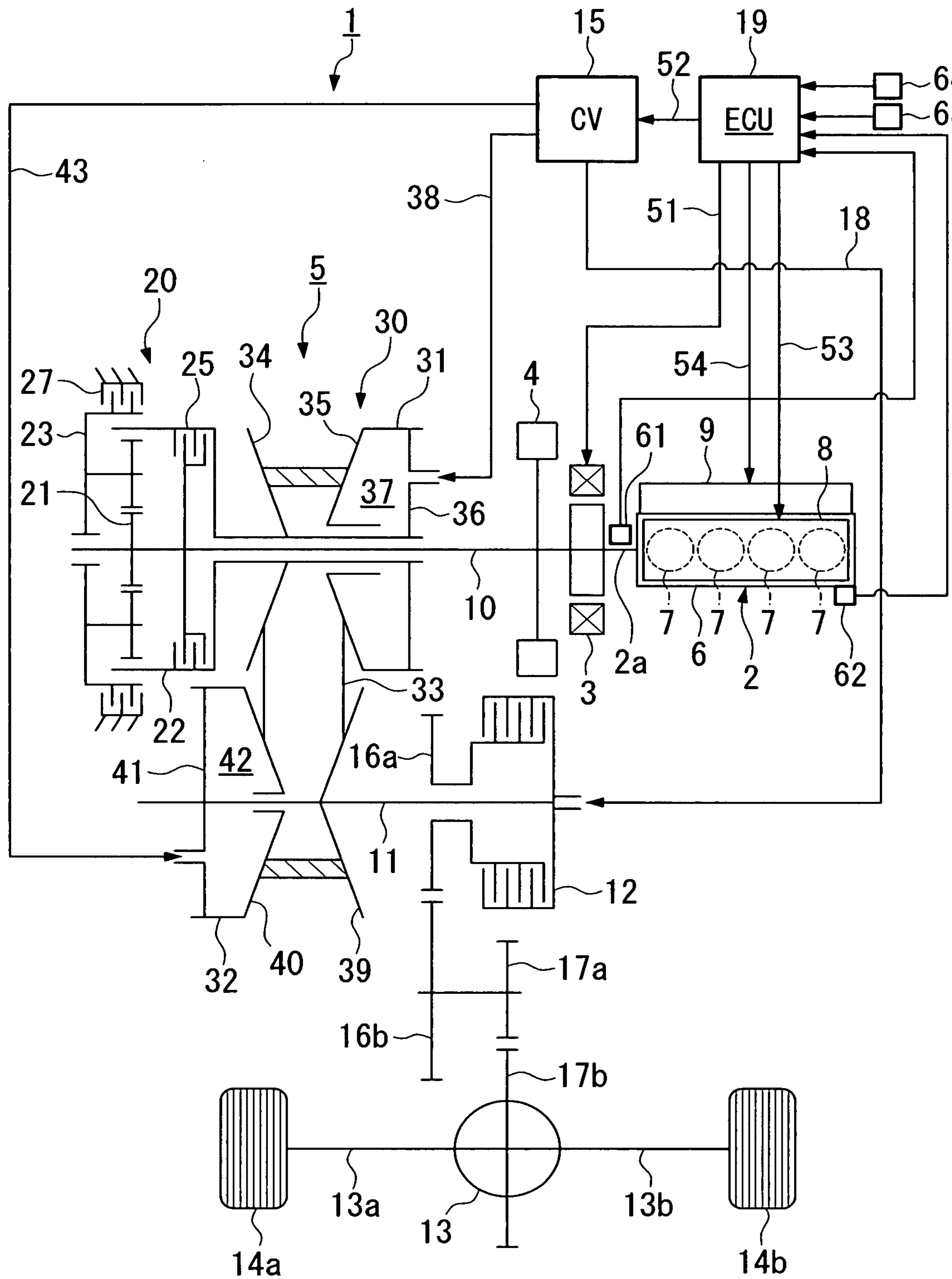
[Abstract]

[Problem to be Solved by the Invention] To improve drivability of a hybrid vehicle in which a drive mode can be switched back and forth between an engine cruise mode and a motor cruise mode.

[Means for Solving the Problem] A clutch control apparatus is provided for a hybrid vehicle in which a drive mode can be switched back and forth between an engine cruise mode in which the vehicle is operated by an engine, and a motor cruise mode in which the vehicle is operated by a motor-generator, the clutch control apparatus includes: a starting clutch provided between the engine and motor-generator and output shafts so as to be able to selectively disconnect the power; and a clutch control means for controlling the engagement degree of the starting clutch when the driving mode of the vehicle is alternately switched between the engine cruise mode and the motor cruise mode, wherein the clutch control means executes a clutch relaxation control operation on the starting clutch when the drive mode is switched between the engine cruise mode and the motor cruise mode, and executes an engagement increasing control operation in which the engagement degree of the starting clutch is increased when the revolution rate of the engine falls below a predetermined value during the clutch relaxation control operation.

[Selected Drawing] FIG. 2

FIG. 1


1
15
19
52
CV
ECU
64
63
43
38
51
18
20
5
30
34
31
25
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23
4
54
53
37
61
9
8
21
36
10
7
6
2a
3
2
62
22
33
42
16a
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12
32
40
39
17a
16b
17b
13a
13
13b
14a
14b

FIG. 2

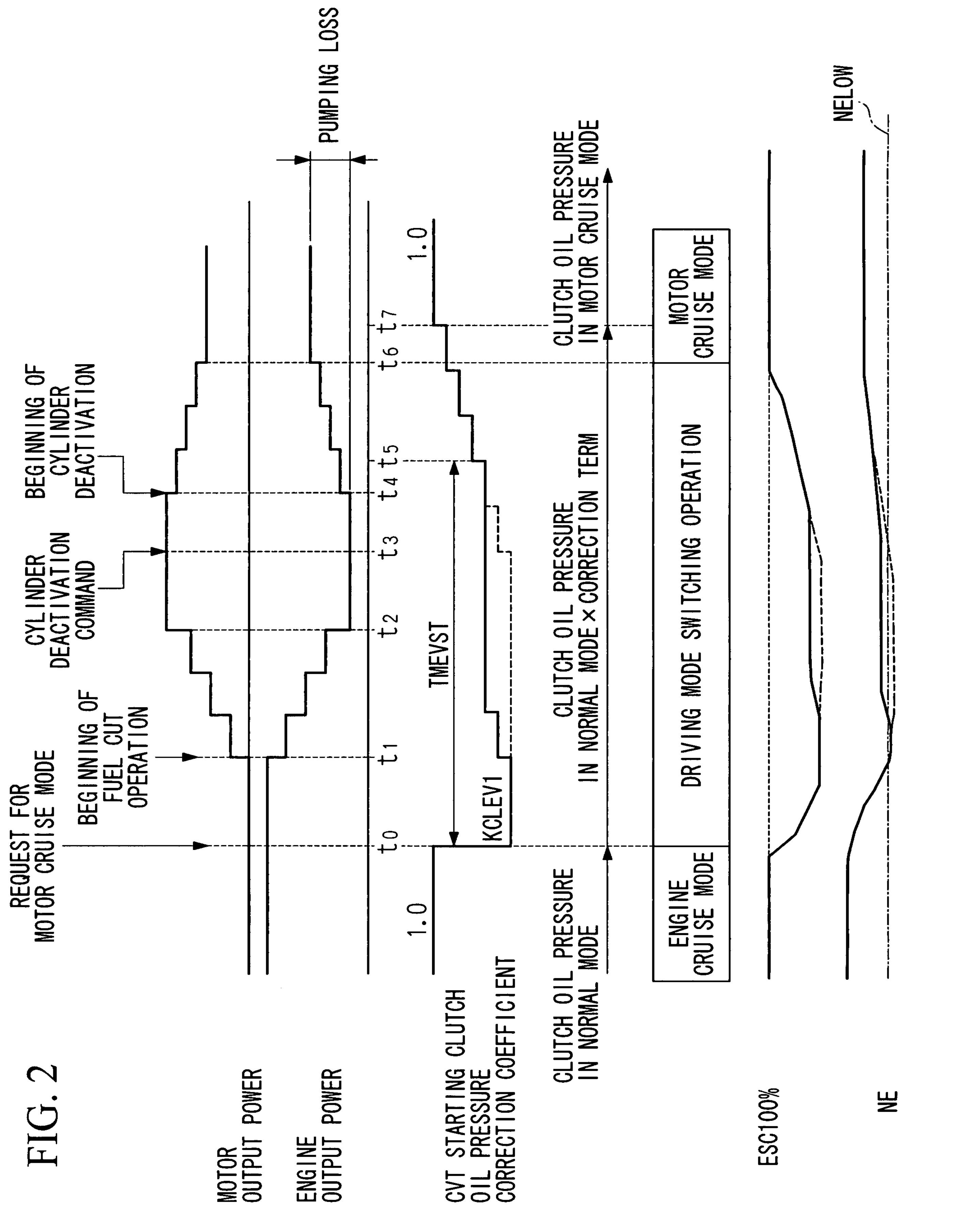
MOTOR OUTPUT POWER
ENGINE OUTPUT POWER
CVT STARTING CLUTCH OIL PRESSURE CORRECTION COEFFICIENT
CLUTCH OIL PRESSURE IN NORMAL MODE
ESC100%
NE
REQUEST FOR MOTOR CRUISE MODE
BEGINNING OF FUEL CUT OPERATION
CYLINDER DEACTIVATION COMMAND
BEGINNING OF CYLINDER DEACTIVATION
PUMPING LOSS
t0
t1
t2
t3
t4
t5
t6
t7
1.0
1.0
TMEVST
KCLEV1
CLUTCH OIL PRESSURE IN NORMAL MODE × CORRECTION TERM
CLUTCH OIL PRESSURE IN MOTOR CRUISE MODE
ENGINE CRUISE MODE
DRIVING MODE SWITCHING OPERATION
MOTOR CRUISE MODE
NELOW

FIG. 3

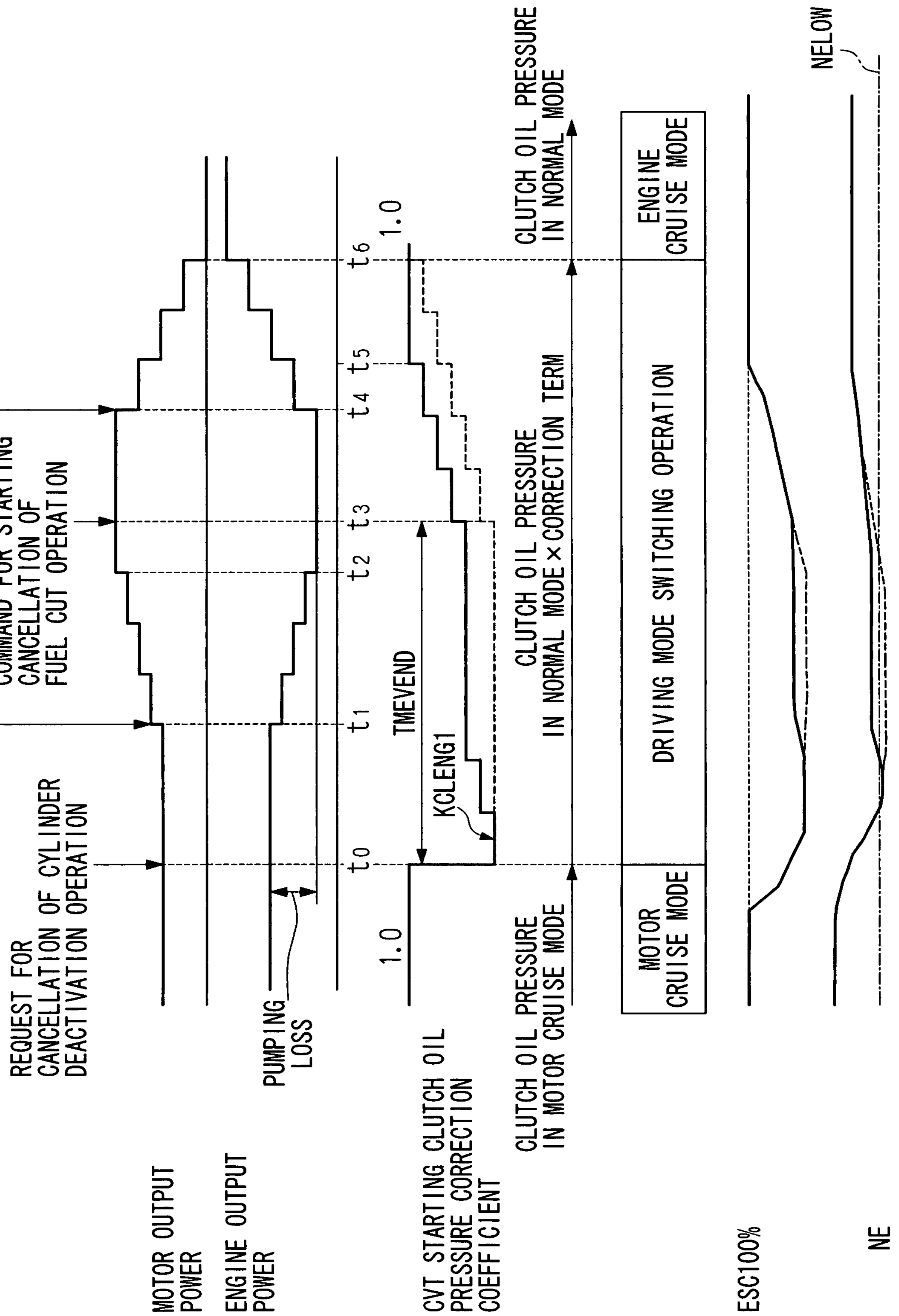
MOTOR OUTPUT POWER
ENGINE OUTPUT POWER
CVT STARTING CLUTCH OIL PRESSURE CORRECTION COEFFICIENT
ESC100%
NE
REQUEST FOR CANCELLATION OF CYLINDER DEACTIVATION OPERATION
BEGINNING OF CANCELLATION OF CYLINDER DEACTIVATION OPERATION
COMMAND FOR STARTING CANCELLATION OF FUEL CUT OPERATION
BEGINNING OF CANCELLATION OF FUEL CUT OPERATION
PUMPING LOSS
1.0
t0
t1
t2
t3
t4
t5
t6
1.0
TMEVEND
KCLENG1
CLUTCH OIL PRESSURE IN MOTOR CRUISE MODE
CLUTCH OIL PRESSURE IN NORMAL MODE × CORRECTION TERM
CLUTCH OIL PRESSURE IN NORMAL MODE
MOTOR CRUISE MODE
DRIVING MODE SWITCHING OPERATION
ENGINE CRUISE MODE
NELOW

FIG. 4

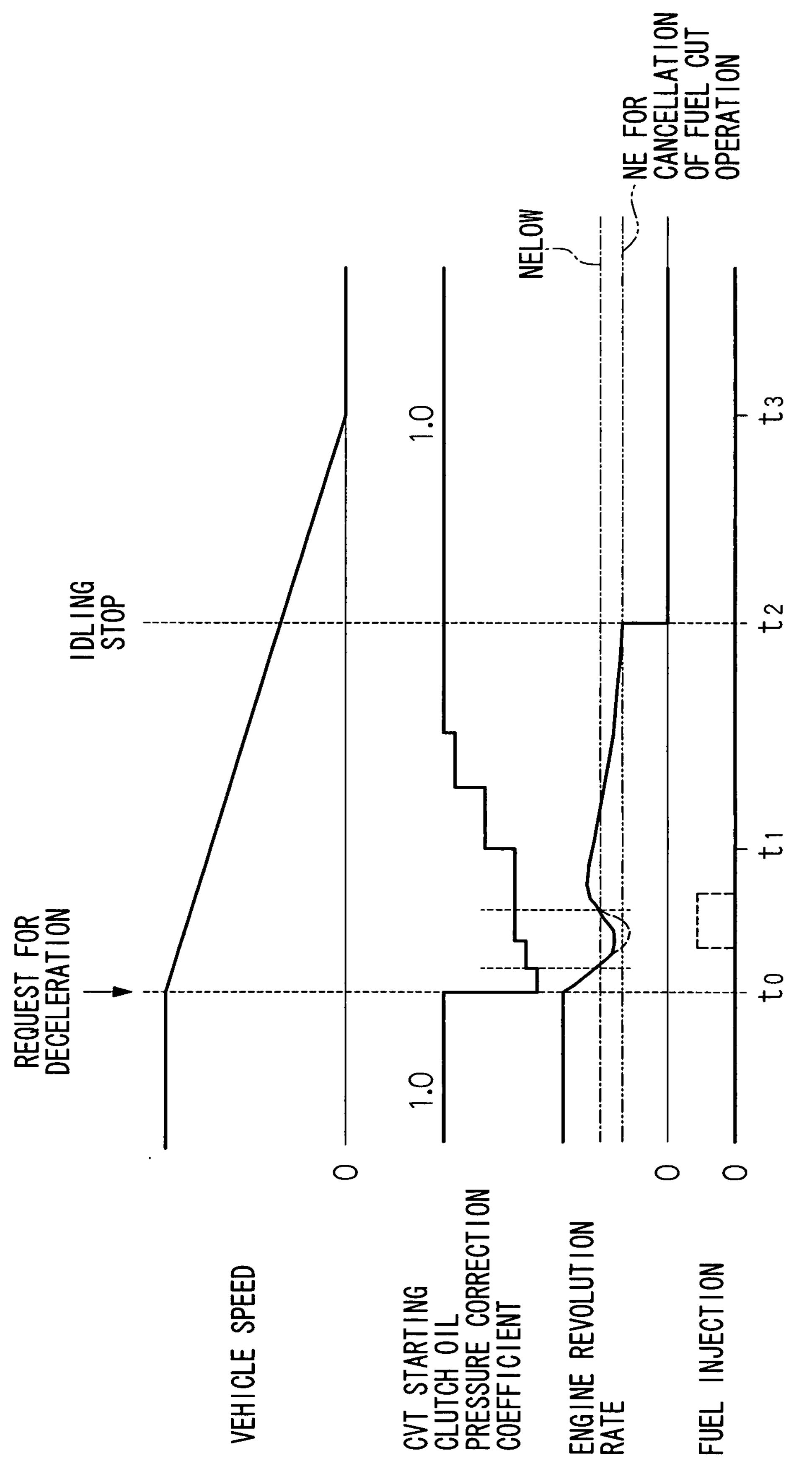
VEHICLE SPEED
CVT STARTING CLUTCH OIL PRESSURE CORRECTION COEFFICIENT
ENGINE REVOLUTION RATE
FUEL INJECTION
REQUEST FOR DECELERATION
IDLING STOP
NELOW
NE FOR CANCELLATION OF FUEL CUT OPERATION
1.0
1.0
0
0
0
0
t0
t1
t2
t3

FIG. 5

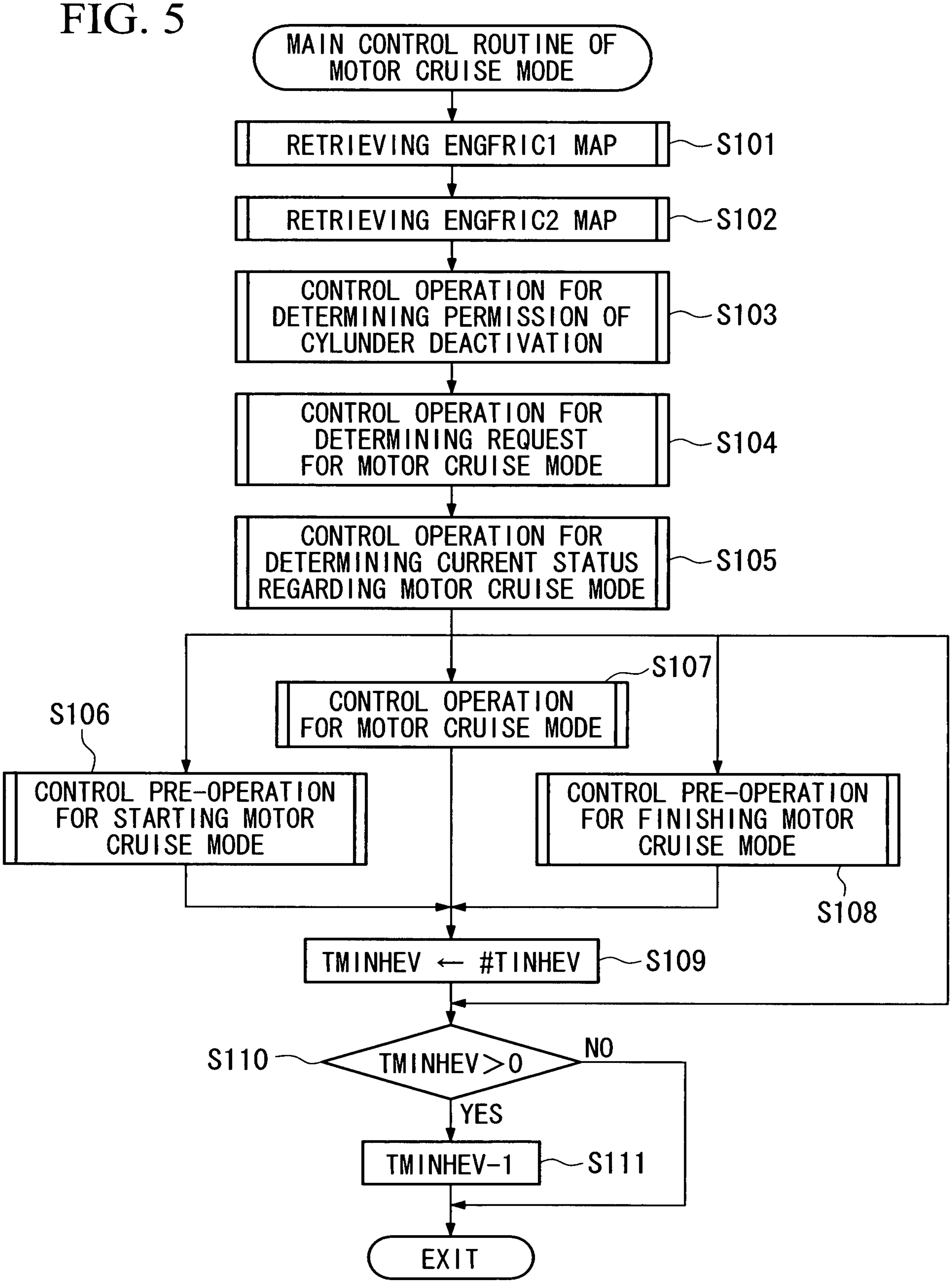
MAIN CONTROL ROUTINE OF MOTOR CRUISE MODE
RETRIEVING ENGFRIC1 MAP
S101
RETRIEVING ENGFRIC2 MAP
S102
CONTROL OPERATION FOR DETERMINING PERMISSION OF CYLUNDER DEACTIVATION
S103
CONTROL OPERATION FOR DETERMINING REQUEST FOR MOTOR CRUISE MODE
S104
CONTROL OPERATION FOR DETERMINING CURRENT STATUS REGARDING MOTOR CRUISE MODE
S105
S107
CONTROL OPERATION FOR MOTOR CRUISE MODE
S106
CONTROL PRE-OPERATION FOR STARTING MOTOR CRUISE MODE
CONTROL PRE-OPERATION FOR FINISHING MOTOR CRUISE MODE
S108
TMINHEV ← #TINHEV
S109
S110
TMINHEV>0
NO
YES
TMINHEV-1
S111
EXIT

FIG. 6

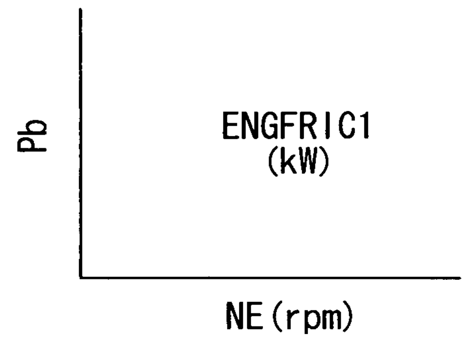

FIG. 7

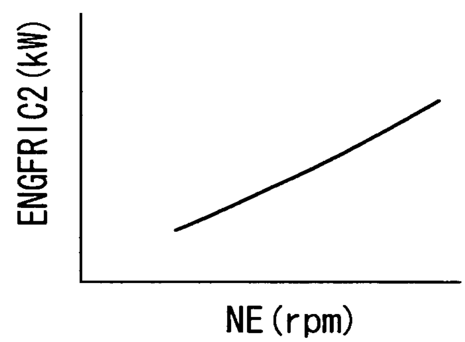

FIG. 8

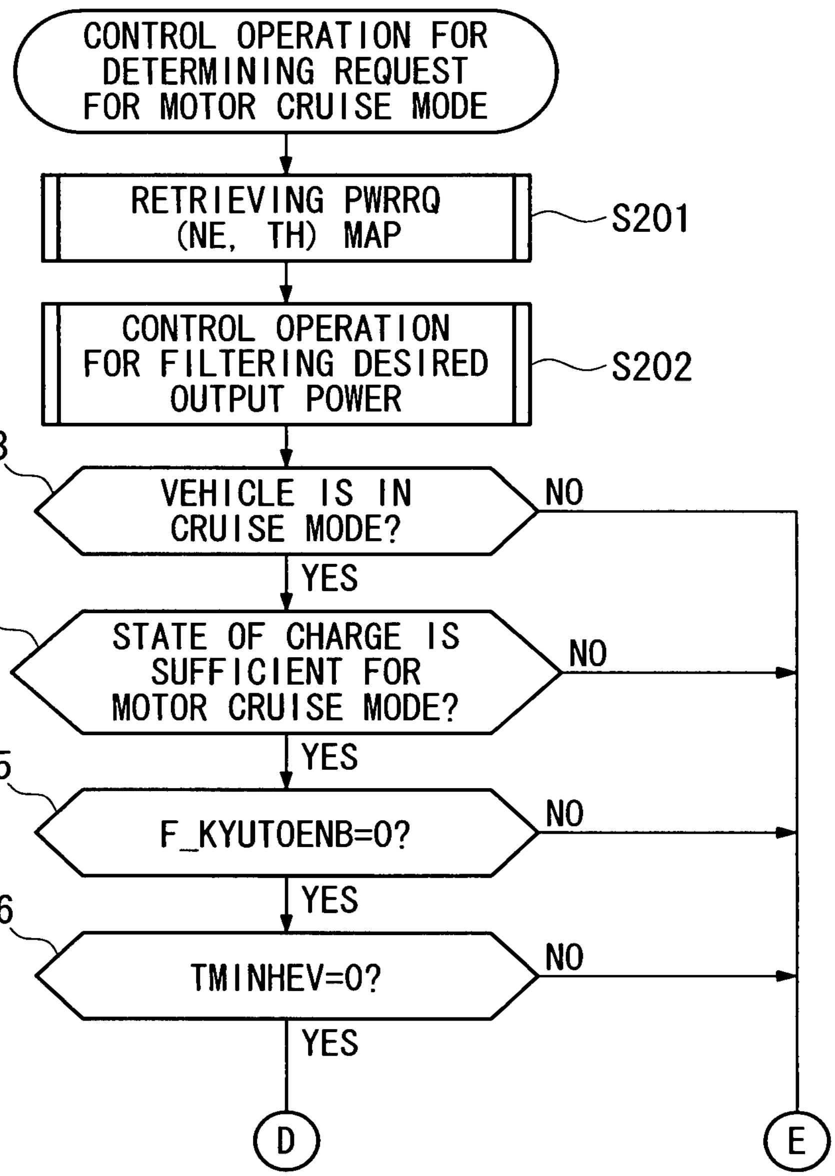
CONTROL OPERATION FOR DETERMINING REQUEST FOR MOTOR CRUISE MODE
RETRIEVING PWRRQ (NE, TH) MAP
S201
CONTROL OPERATION FOR FILTERING DESIRED OUTPUT POWER
S202
S203
VEHICLE IS IN CRUISE MODE?
NO
YES
S204
STATE OF CHARGE IS SUFFICIENT FOR MOTOR CRUISE MODE?
NO
YES
S205
F_KYUTOENB=0?
NO
YES
S206
TMINHEV=0?
NO
YES
D
E

FIG. 9

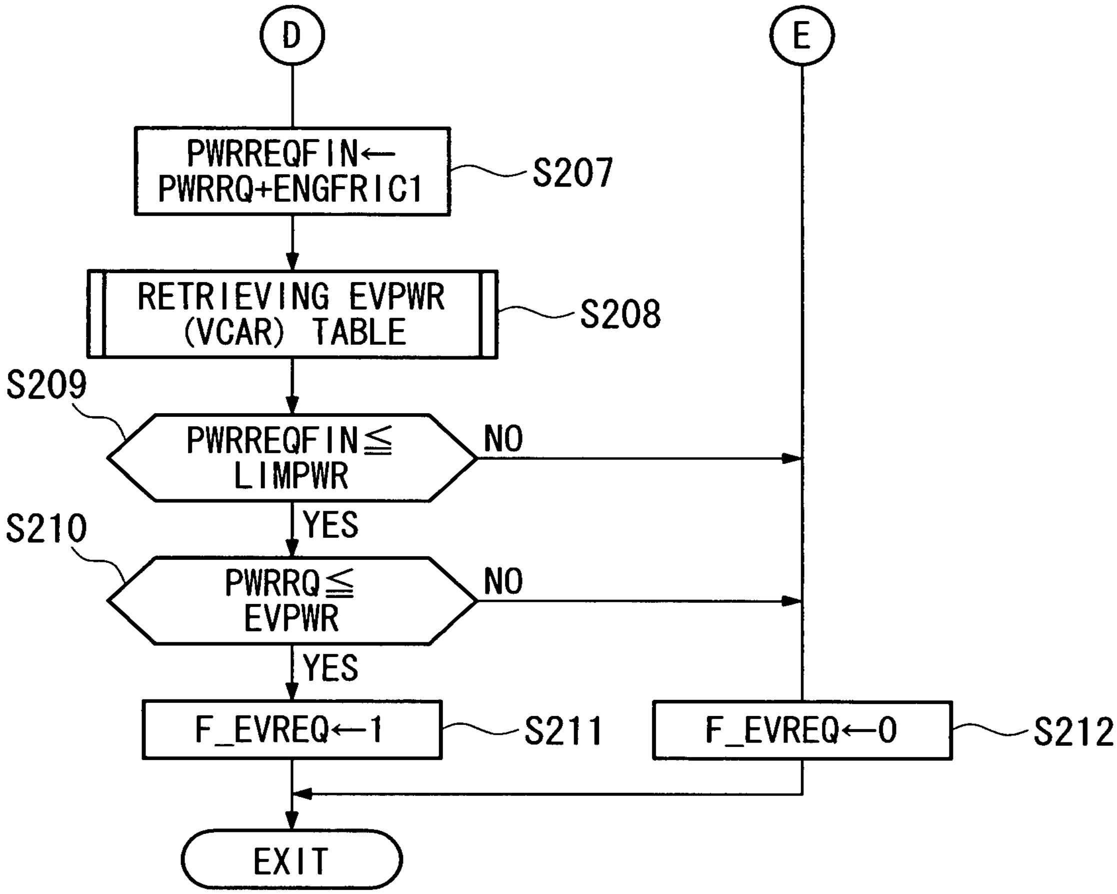
D
E
PWRREQFIN←
PWRRQ+ENGFRIC1
S207
RETRIEVING EVPWR
(VCAR) TABLE
S208
S209
PWRREQFIN≦
LIMPWR
NO
YES
S210
PWRRQ≦
EVPWR
NO
YES
F_EVREQ←1
S211
F_EVREQ←0
S212
EXIT

FIG. 10

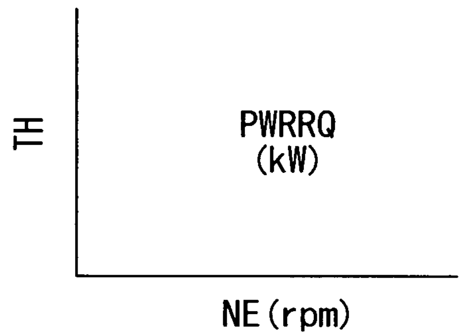

FIG. 11

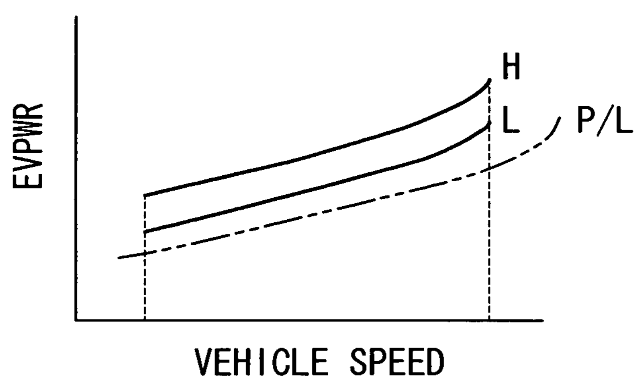

FIG. 12

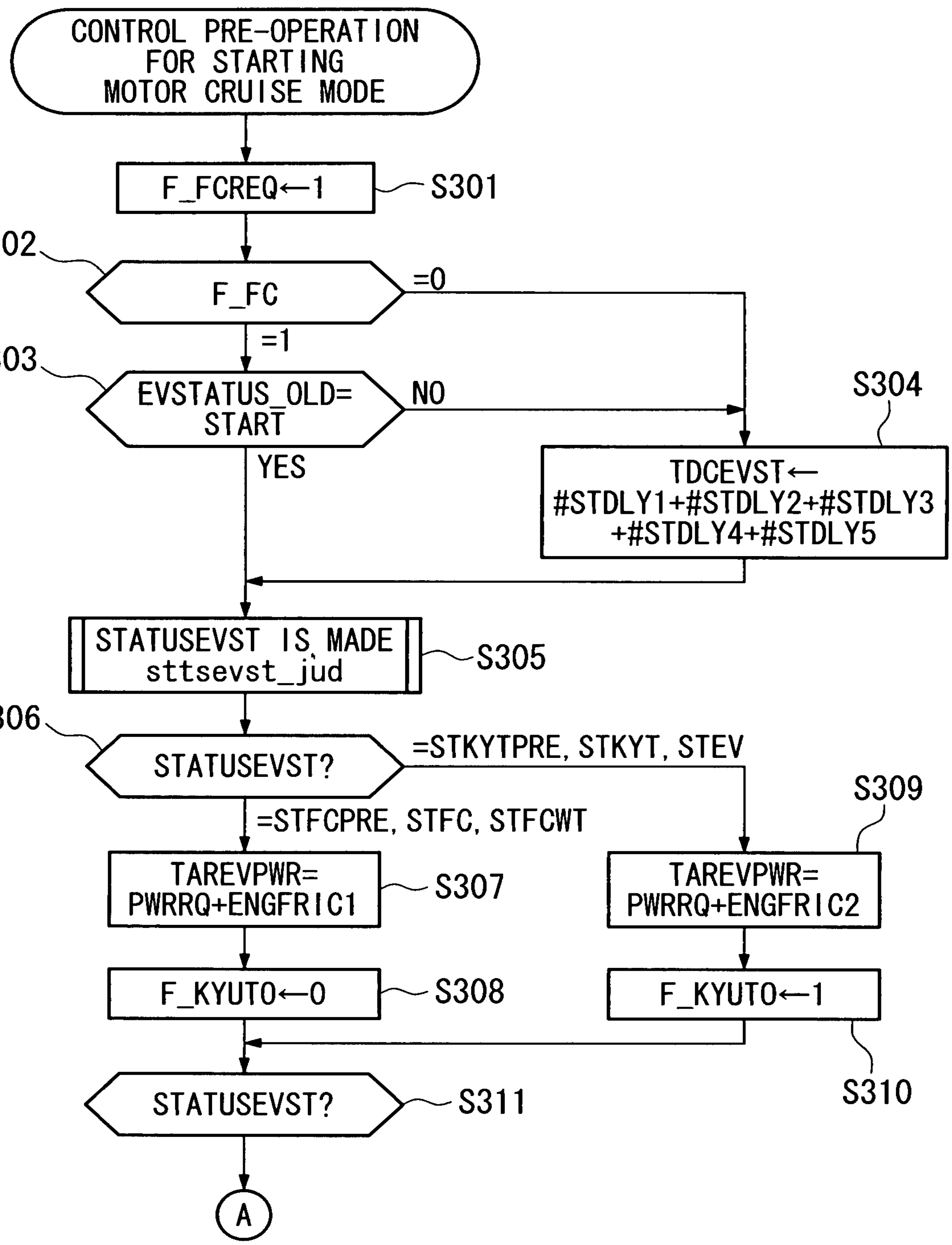
CONTROL PRE-OPERATION FOR STARTING MOTOR CRUISE MODE
F_FCREQ←1
S301
S302
F_FC
=0
=1
S303
EVSTATUS_OLD= START
NO
YES
S304
TDCEVST← #STDLY1+#STDLY2+#STDLY3 +#STDLY4+#STDLY5
STATUSEVST IS MADE sttsevst_jud
S305
S306
STATUSEVST?
=STKYTPRE, STKYT, STEV
S309
=STFCPRE, STFC, STFCWT
TAREVPWR= PWRRQ+ENGFRIC1
S307
TAREVPWR= PWRRQ+ENGFRIC2
F_KYUTO←0
S308
F_KYUTO←1
S310
STATUSEVST?
S311
A

FIG. 13

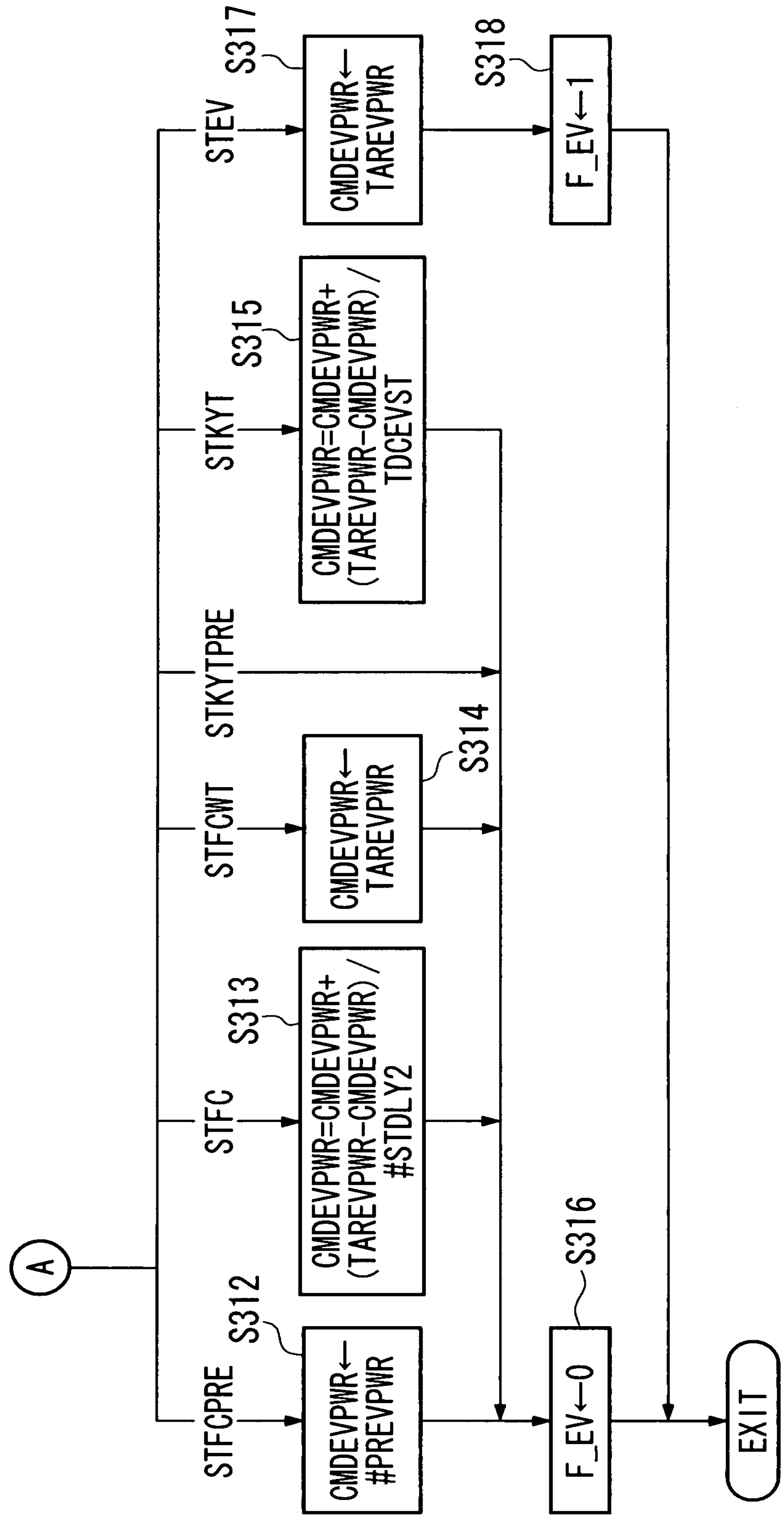
A
STFCPRE
STFC
STFCWT
STKYTPRE
STKYT
STEV
S312
CMDEVPWR← #PREVPWR
S313
CMDEVPWR=CMDEVPWR+ (TAREVPWR−CMDEVPWR) / #STDLY2
S314
CMDEVPWR← TAREVPWR
S315
CMDEVPWR=CMDEVPWR+ (TAREVPWR−CMDEVPWR) / TDCEVST
S317
CMDEVPWR← TAREVPWR
S316
F_EV←0
S318
F_EV←1
EXIT

FIG. 14

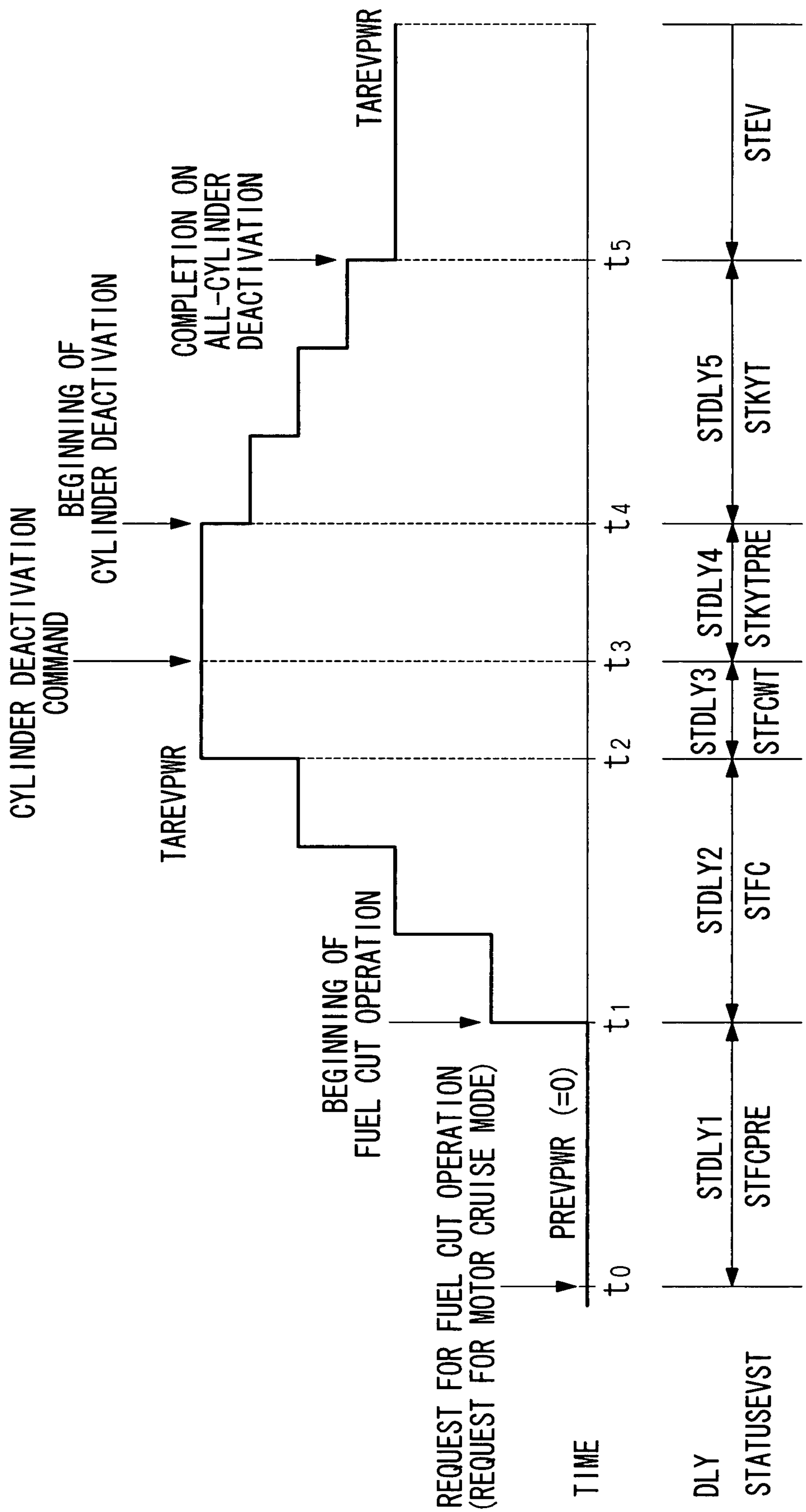
REQUEST FOR FUEL CUT OPERATION (REQUEST FOR MOTOR CRUISE MODE)
TIME
DLY
STATUSEVST
PREVPWR (=0)
BEGINNING OF FUEL CUT OPERATION
TAREVPWR
CYLINDER DEACTIVATION COMMAND
BEGINNING OF CYLINDER DEACTIVATION
COMPLETION ON ALL-CYLINDER DEACTIVATION
TAREVPWR
t0
t1
t2
t3
t4
t5
STDLY1
STDLY2
STDLY3
STDLY4
STDLY5
STFCPRE
STFC
STFCWT
STKYTPRE
STKYT
STEV

FIG. 15

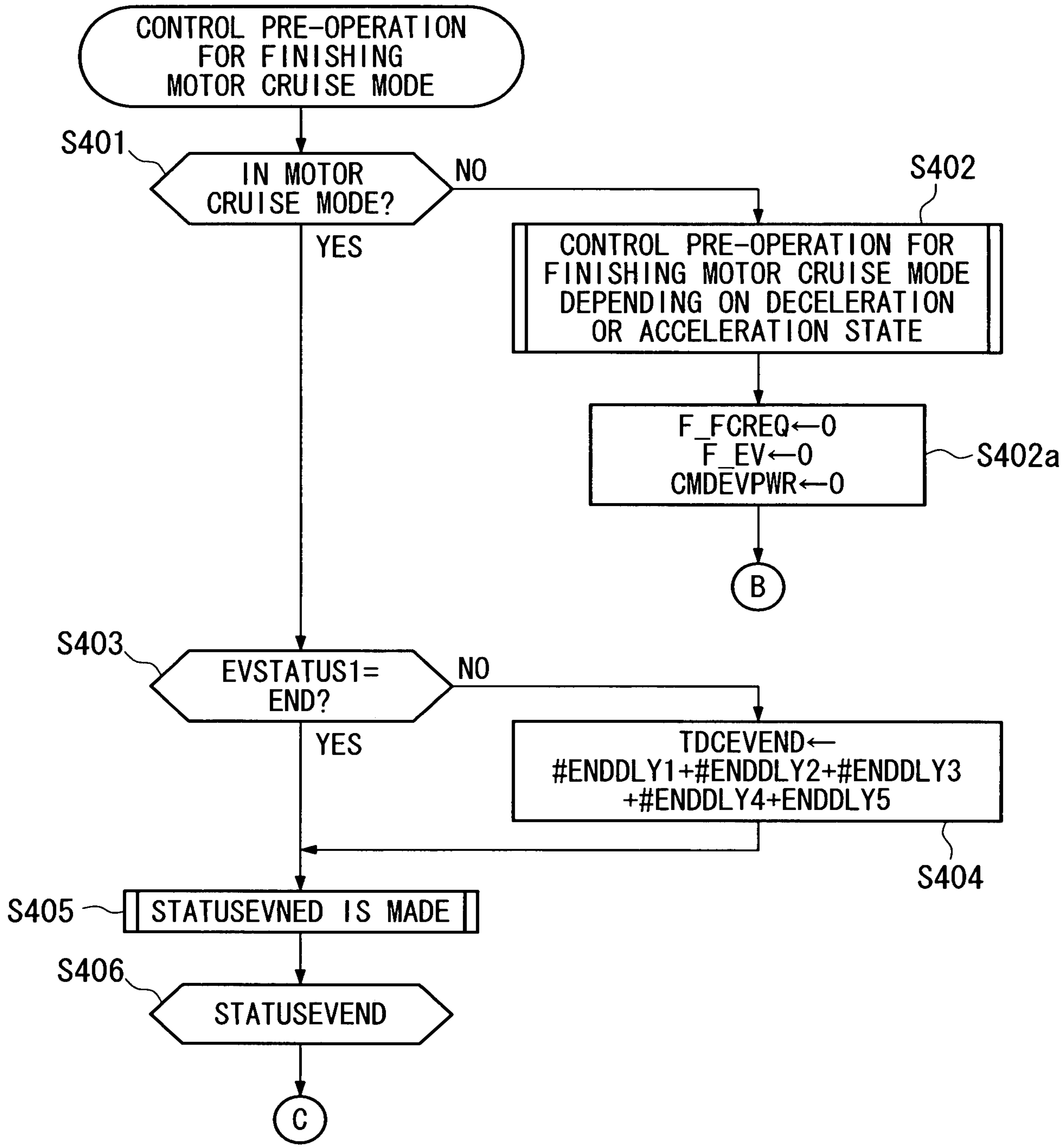
CONTROL PRE-OPERATION FOR FINISHING MOTOR CRUISE MODE
S401
IN MOTOR CRUISE MODE?
NO
YES
S402
CONTROL PRE-OPERATION FOR FINISHING MOTOR CRUISE MODE DEPENDING ON DECELERATION OR ACCELERATION STATE
F_FCREQ←0
F_EV←0
CMDEVPWR←0
S402a
B
S403
EVSTATUS1= END?
NO
YES
TDCEVEND← #ENDDLY1+#ENDDLY2+#ENDDLY3 +#ENDDLY4+ENDDLY5
S404
S405
STATUSEVNED IS MADE
S406
STATUSEVEND
C

FIG. 16

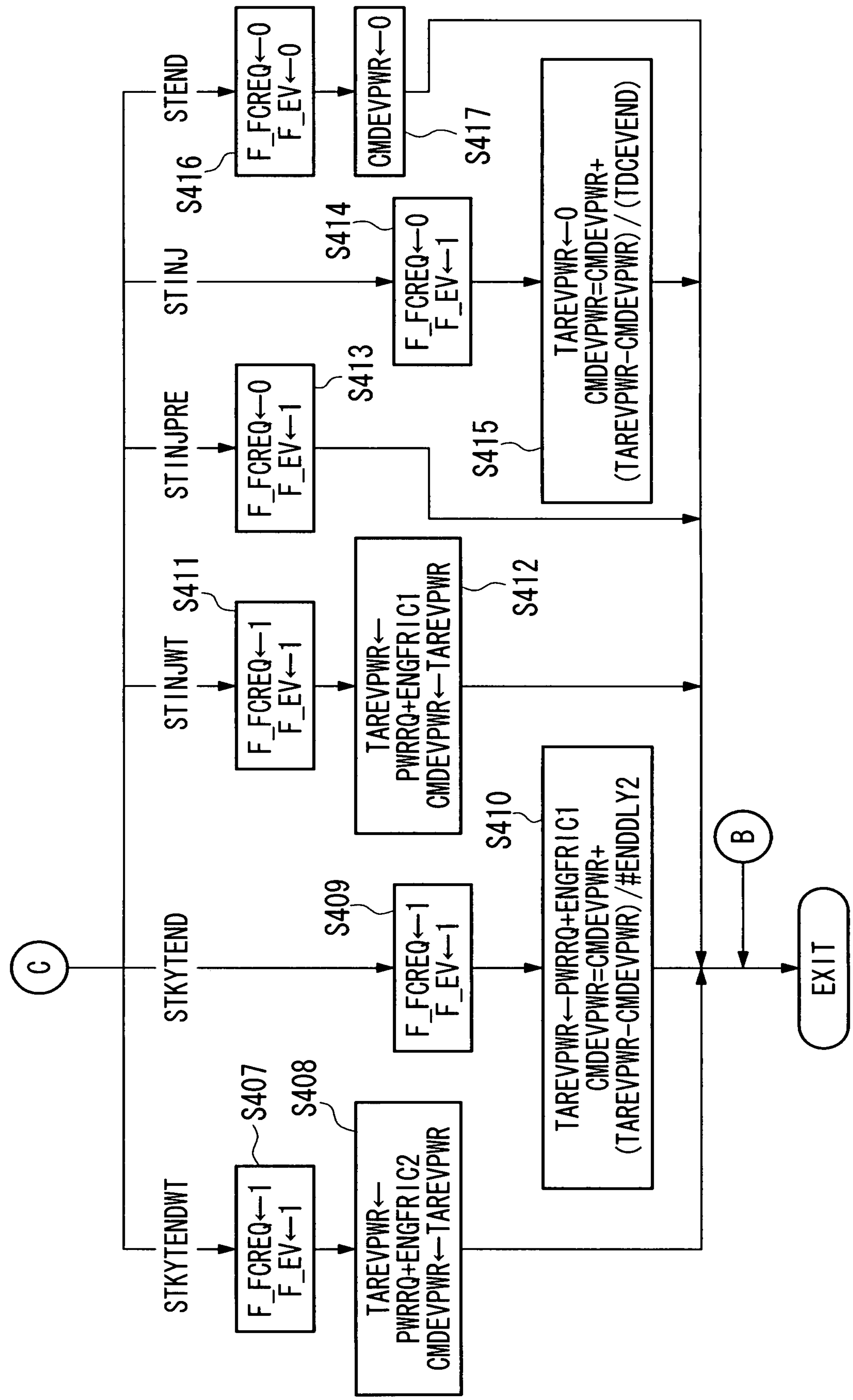
C
STKYTENDWT
STKYTEND
STINJWT
STINJPRE
STINJ
STEND
S407
F_FCREQ←1
F_EV←1
S408
TAREVPWR←
PWRRQ+ENGFRIC2
CMDEVPWR←TAREVPWR
S409
F_FCREQ←1
F_EV←1
S410
TAREVPWR←PWRRQ+ENGFRIC1
CMDEVPWR=CMDEVPWR+
(TAREVPWR-CMDEVPWR)/#ENDDLY2
S411
F_FCREQ←1
F_EV←1
S412
TAREVPWR←
PWRRQ+ENGFRIC1
CMDEVPWR←TAREVPWR
S413
F_FCREQ←0
F_EV←1
S414
F_FCREQ←0
F_EV←1
S415
TAREVPWR←0
CMDEVPWR=CMDEVPWR+
(TAREVPWR-CMDEVPWR)/(TDCEVEND)
S416
F_FCREQ←0
F_EV←0
S417
CMDEVPWR←0
B
EXIT

FIG. 17

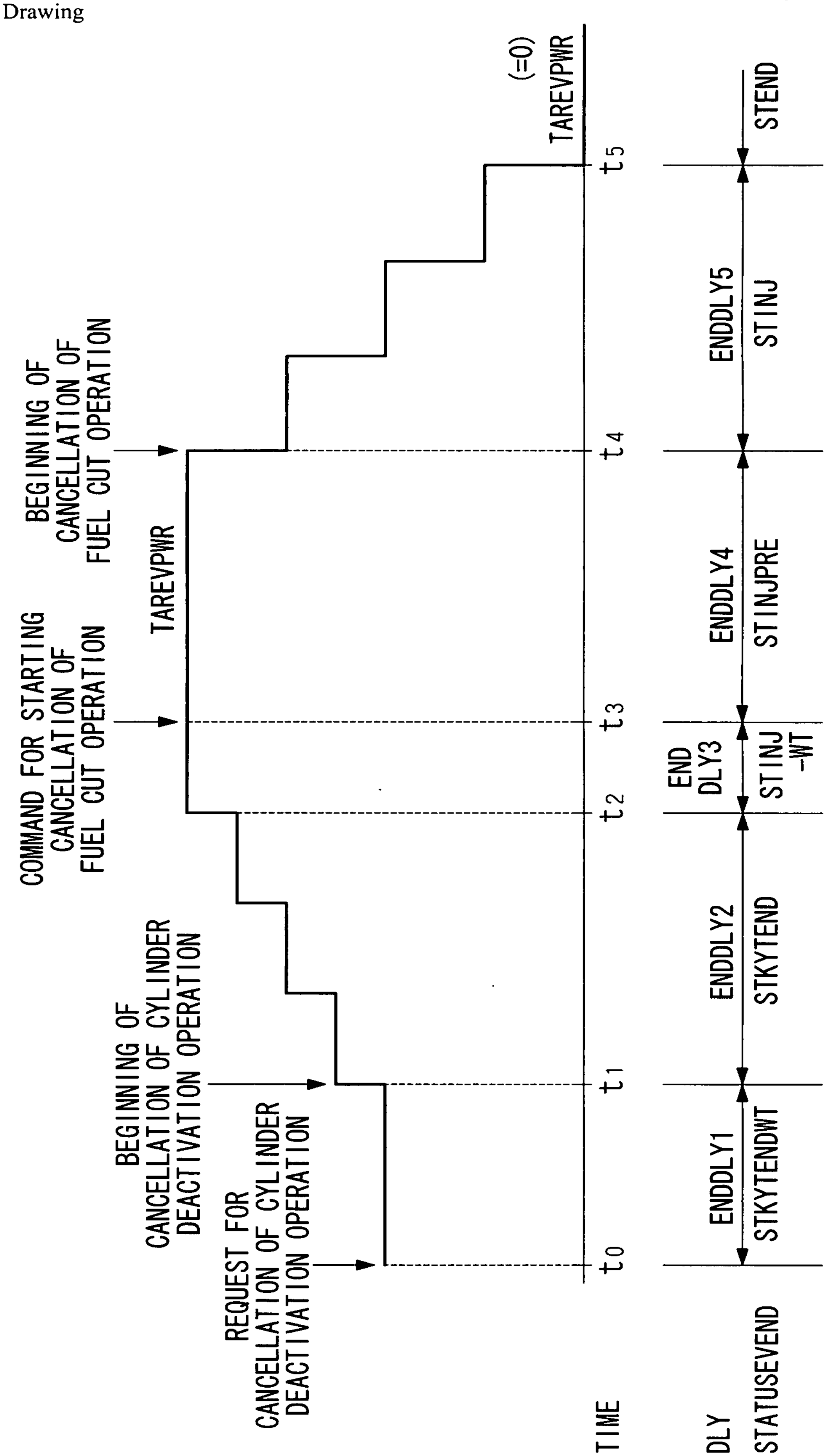
REQUEST FOR CANCELLATION OF CYLINDER DEACTIVATION OPERATION
BEGINNING OF CANCELLATION OF CYLINDER DEACTIVATION OPERATION
COMMAND FOR STARTING CANCELLATION OF FUEL CUT OPERATION
TAREVPWR
BEGINNING OF CANCELLATION OF FUEL CUT OPERATION
TAREVPWR (=0)
TIME
t0
t1
t2
t3
t4
t5
DLY
STATUSEVEND
ENDDLY1
STKYTENDWT
ENDDLY2
STKYTEND
END DLY3
STINJ -WT
ENDDLY4
STINJPRE
ENDDLY5
STINJ
STEND

FIG. 18

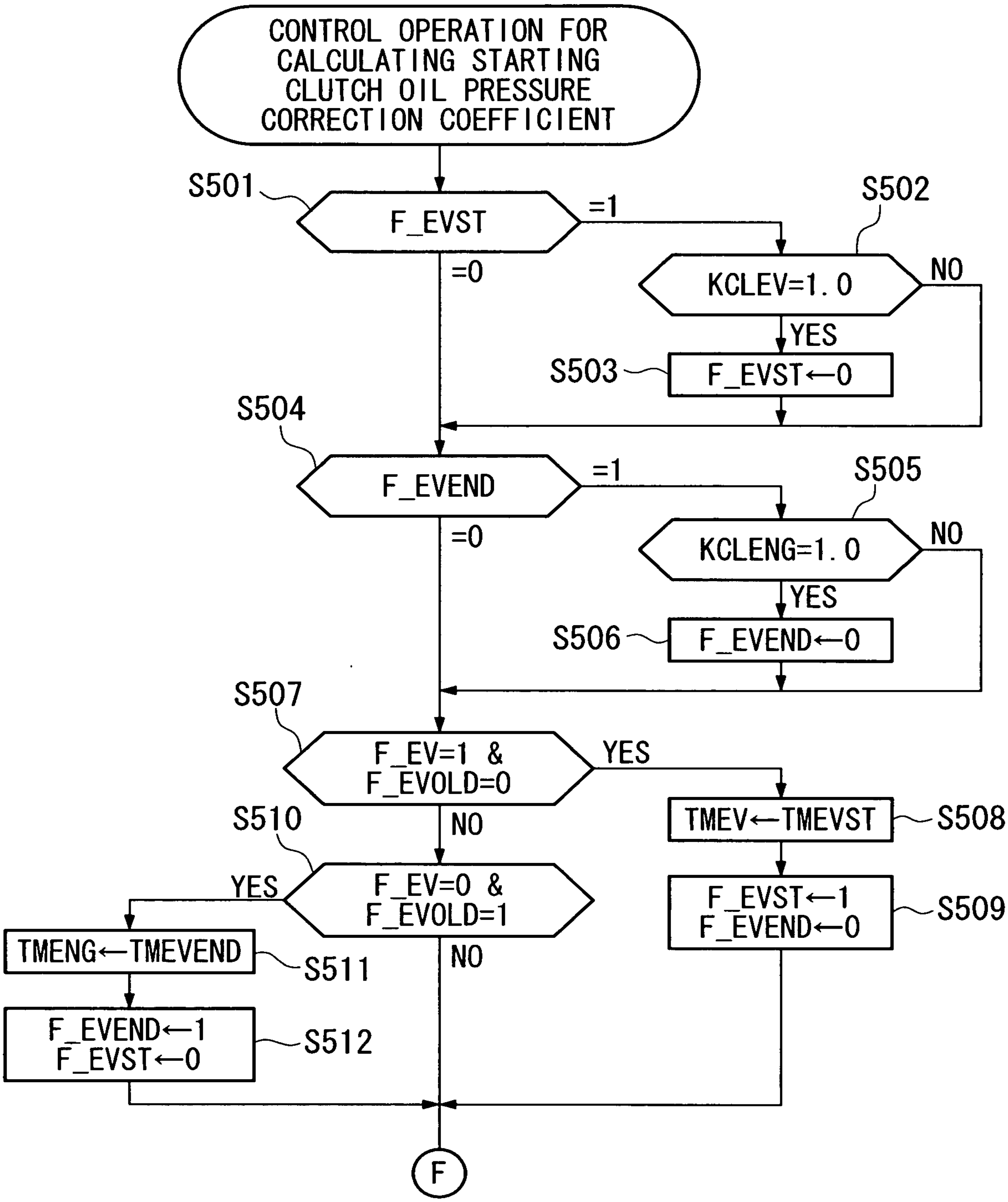
CONTROL OPERATION FOR CALCULATING STARTING CLUTCH OIL PRESSURE CORRECTION COEFFICIENT
S501
F_EVST
=1
=0
S502
KCLEV=1.0
NO
YES
S503
F_EVST←0
S504
F_EVEND
=1
=0
S505
KCLENG=1.0
NO
YES
S506
F_EVEND←0
S507
F_EV=1 &
F_EVOLD=0
YES
NO
TMEV←TMEVST
S508
F_EVST←1
F_EVEND←0
S509
S510
F_EV=0 &
F_EVOLD=1
YES
NO
TMENG←TMEVEND
S511
F_EVEND←1
F_EVST←0
S512
F

FIG. 19

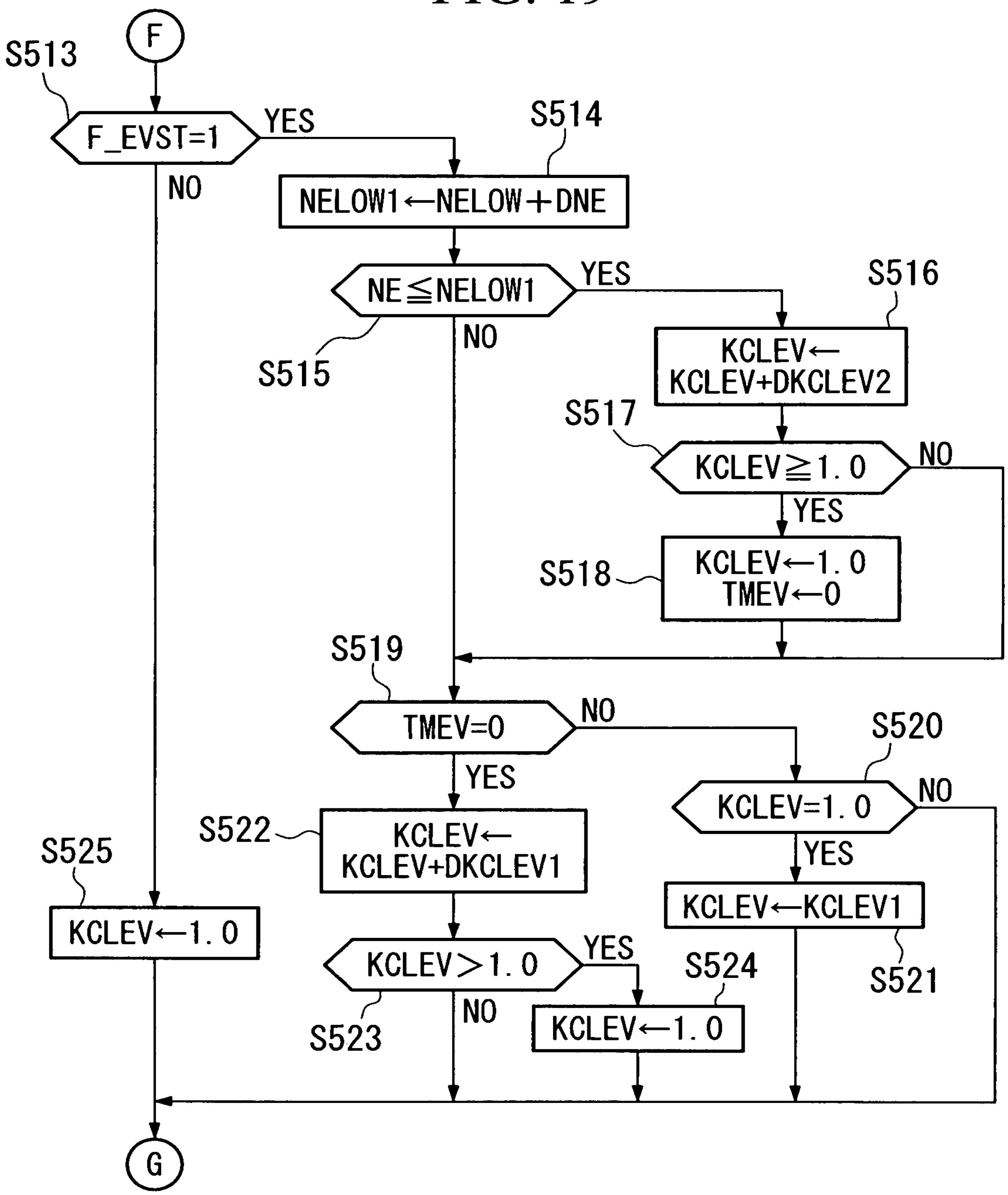
F
S513
F_EVST=1
YES
NO
S514
NELOW1←NELOW+DNE
NE≦NELOW1
YES
NO
S515
S516
KCLEV←
KCLEV+DKCLEV2
S517
KCLEV≧1. 0
NO
YES
S518
KCLEV←1. 0
TMEV←0
S519
TMEV=0
NO
YES
S520
KCLEV=1. 0
NO
YES
KCLEV←KCLEV1
S521
S522
KCLEV←
KCLEV+DKCLEV1
KCLEV>1. 0
YES
NO
S523
S524
KCLEV←1. 0
S525
KCLEV←1. 0
G

FIG. 20

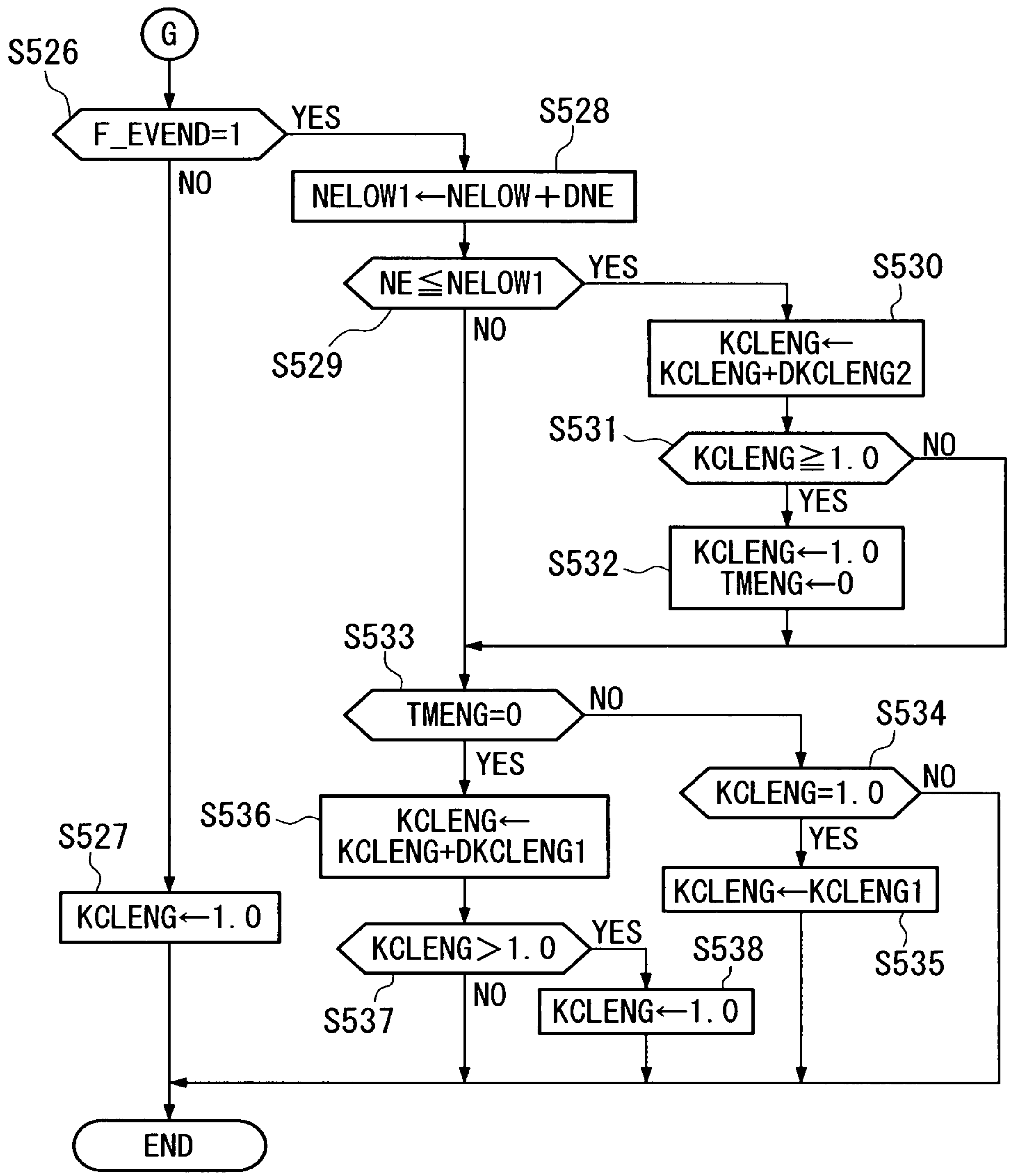
G
S526
F_EVEND=1
YES
NO
S528
NELOW1←NELOW+DNE
NE≦NELOW1
YES
NO
S529
S530
KCLENG←
KCLENG+DKCLENG2
S531
KCLENG≧1. 0
NO
YES
S532
KCLENG←1. 0
TMENG←0
S533
TMENG=0
NO
YES
S534
KCLENG=1. 0
NO
YES
S536
KCLENG←
KCLENG+DKCLENG1
KCLENG←KCLENG1
S535
S527
KCLENG←1. 0
KCLENG>1. 0
YES
NO
S537
S538
KCLENG←1. 0
END

FIG. 21

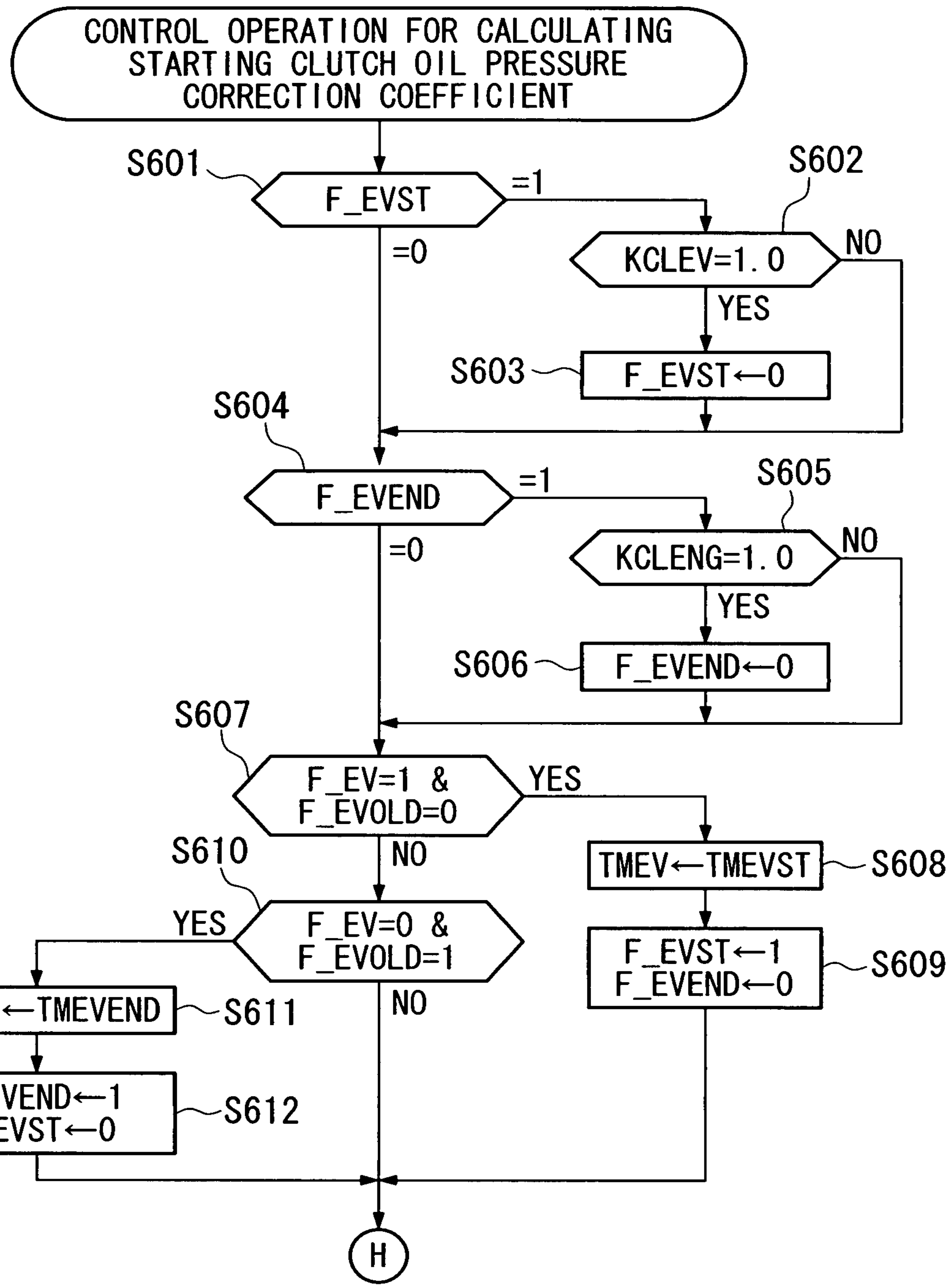
CONTROL OPERATION FOR CALCULATING STARTING CLUTCH OIL PRESSURE CORRECTION COEFFICIENT
S601
F_EVST
=1
=0
S602
KCLEV=1. 0
NO
YES
S603
F_EVST←0
S604
F_EVEND
=1
=0
S605
KCLENG=1. 0
NO
YES
S606
F_EVEND←0
S607
F_EV=1 & F_EVOLD=0
YES
NO
TMEV←TMEVST
S608
F_EVST←1
F_EVEND←0
S609
S610
F_EV=0 & F_EVOLD=1
YES
NO
TMENG←TMEVEND
S611
F_EVEND←1
F_EVST←0
S612
H

FIG. 22

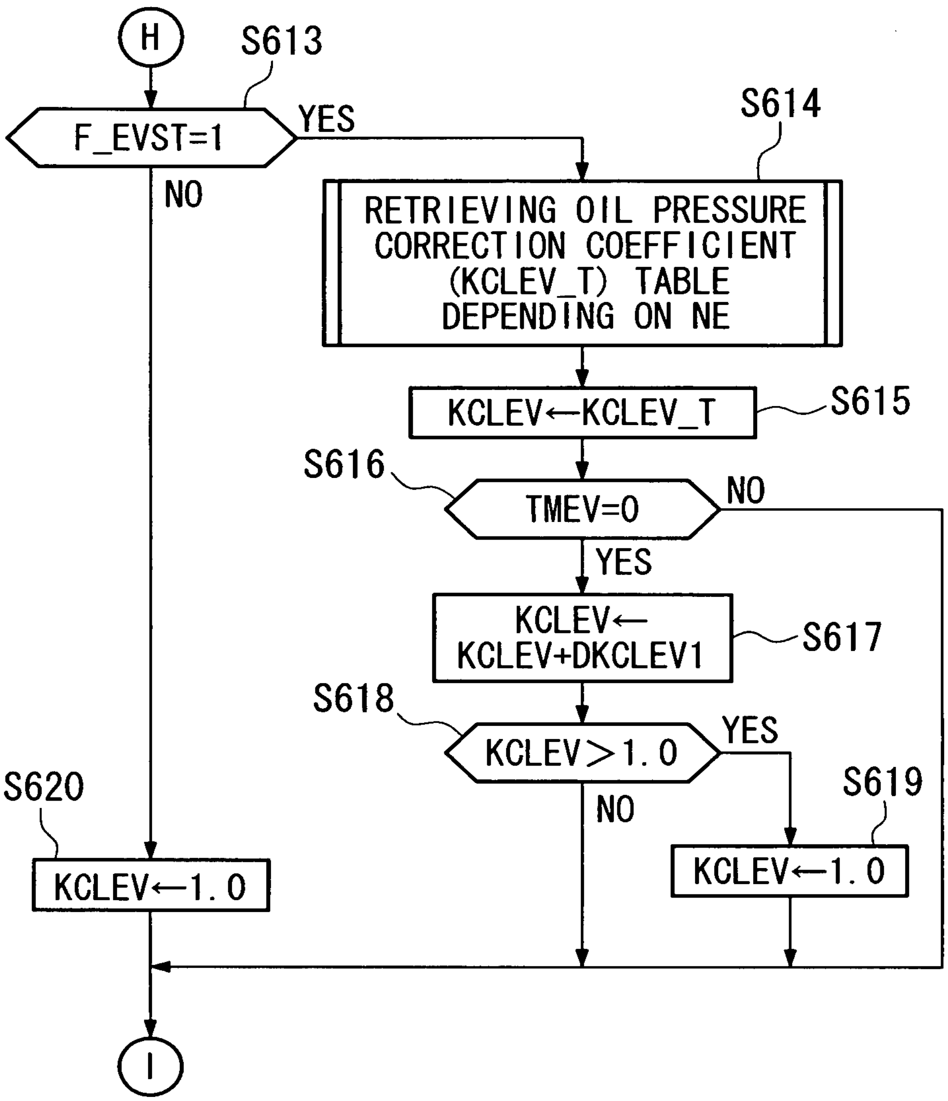
H
S613
F_EVST=1
YES
NO
S614
RETRIEVING OIL PRESSURE CORRECTION COEFFICIENT (KCLEV_T) TABLE DEPENDING ON NE
KCLEV←KCLEV_T
S615
S616
TMEV=0
NO
YES
KCLEV← KCLEV+DKCLEV1
S617
S618
KCLEV>1.0
YES
NO
S619
KCLEV←1.0
S620
KCLEV←1.0
I

FIG. 23

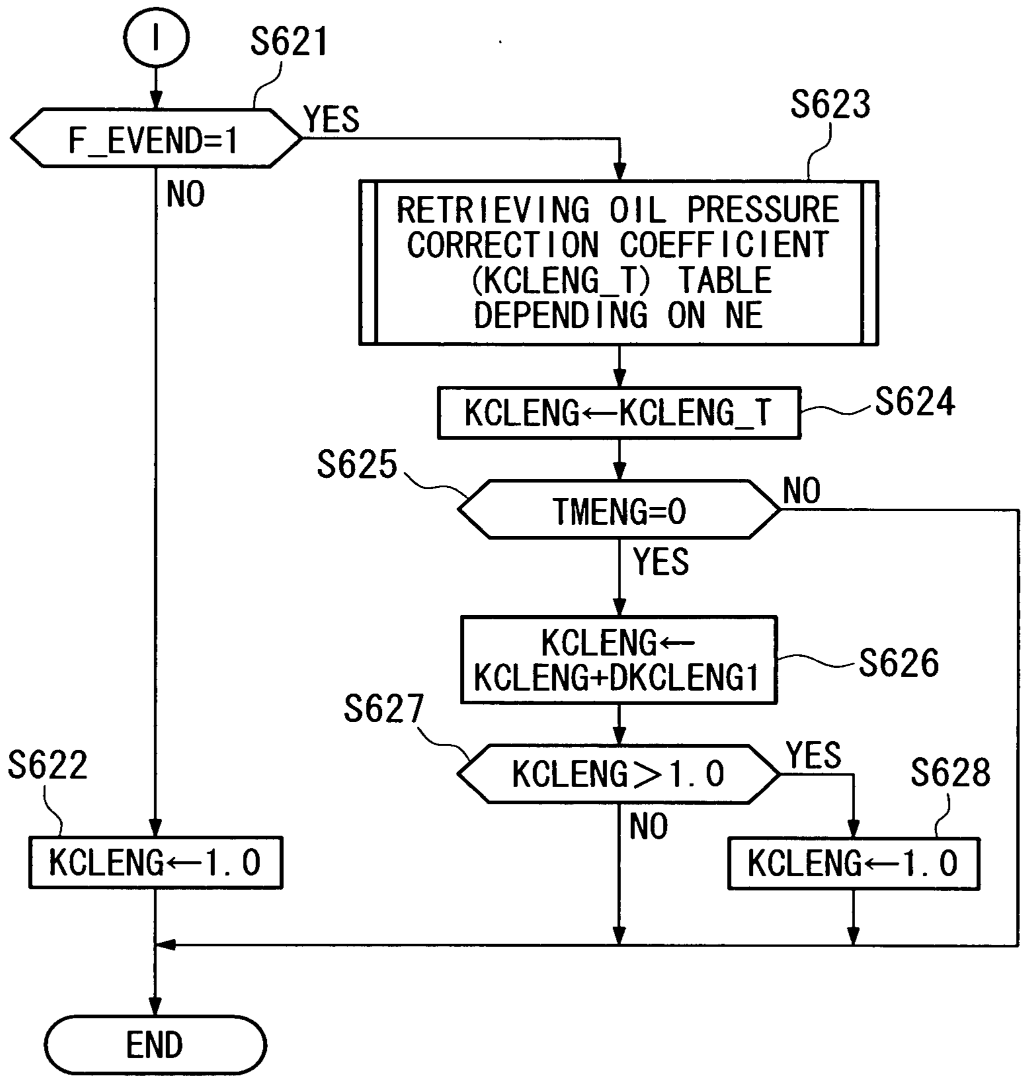
I
S621
F_EVEND=1
YES
NO
S623
RETRIEVING OIL PRESSURE CORRECTION COEFFICIENT (KCLENG_T) TABLE DEPENDING ON NE
KCLENG←KCLENG_T
S624
S625
TMENG=0
NO
YES
KCLENG←
KCLENG+DKCLENG1
S626
S627
KCLENG>1.0
YES
NO
S628
S622
KCLENG←1.0
KCLENG←1.0
END

FIG. 24

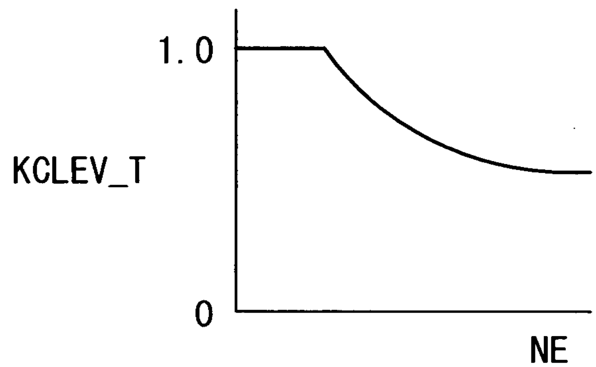

FIG. 25